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IN

BOTANY

WILLIAM ALBERT SETCHELL

EDITOR

VOLUME 2

WITH 29 PLATES

BERKELEY
THE UNIVERSITY PRESS
1904-1907

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CONTENTS.

PAGE

No. 1. A Review of Californian Polemoniaceae, by Jessie Milliken. Pls. 1-11 1-71
Index 69

No. 2. Contributions to Cytological Technique, by W. J. V. Osterhout. Five text-figures 73-90
A Single Freezing Microtome 73
Fixation in Vacuo 78
A Single Slide Holder 81
A Rapid Method of Mounting in Aqueous Media 83
Embedding Microscopic Algae 85
Embedding with Incomplete Dehydration 87

No. 3. Limu, by William Albert Setchell 91-113

No. 4. Post-embryonal Stages of the Laminariaceae, by William Albert Setchell. Pls. 12-14 115-138
Bibliography 131

No. 5. Regeneration among Kelps, by William Albert Setchell. Pls. 15-17 139-168
Bibliography 161

No. 6. A New Genus of Ascomycetous Fungi, by Nathaniel Lyon Gardner. Pl. 18 169-180

No. 7. Teratology in the Flowers of two Californian Willows, by William Warner Mott. Pls. 19-20 181-226
Bibliography 219

No. 8. The Resistance of Certain Marine Algae to Changes in Osmotic Pressure and Temperature (*Preliminary Communication*), by W. J. V. Osterhout 227-228

No. 9. The Rôle of Osmotic Pressure in Marine Plates (*Preliminary Communication*), by W. J. V. Osterhout 229-230

No. 10. On the Importance of Physiologically Balanced Solutions for Plants (*Preliminary Communication*), by W. J. V. Osterhout 231-234

No. 11. The Antitoxic Action of Potassium on Magnesium (*Preliminary Communication*), by W. J. V. Osterhout 235-236

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PAGE

No. 12. Cytological Studies in Cyanophyceae, by Nathaniel Lyon Gardner. Pls. 21-26 237-296
Bibliography 283

No. 13. On a Small Collection of Mosses from Alaska, by J. Cardot and T. Thériot. Pls. 27-28 297-308

No. 14. Some Unreported Alaskan Sphagna, together with a Summary of the Cryptogamic Work of the University of California Botanical Expedition to Alaska in 1899, by William Albert Setchell 309-315

No. 15. On Nutrient and Balanced Solutions, by W. J. V. Osterhout 317-318

No. 16. A Synopsis of North American Godetias, by Willis Linn Jepson. Pl. 29 319-354
Index 353

Index to the Volume 355

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BOTANY

Vol. 2, pp. 1-71, Pls. 1-11 May 10, 1904

A REVIEW OF CALIFORNIAN POLEMONIACEAE

WITH ELEVEN PLATES

BY

JESSIE MILLIKEN

BERKELEY

THE UNIVERSITY PRESS

PRICE $0.75

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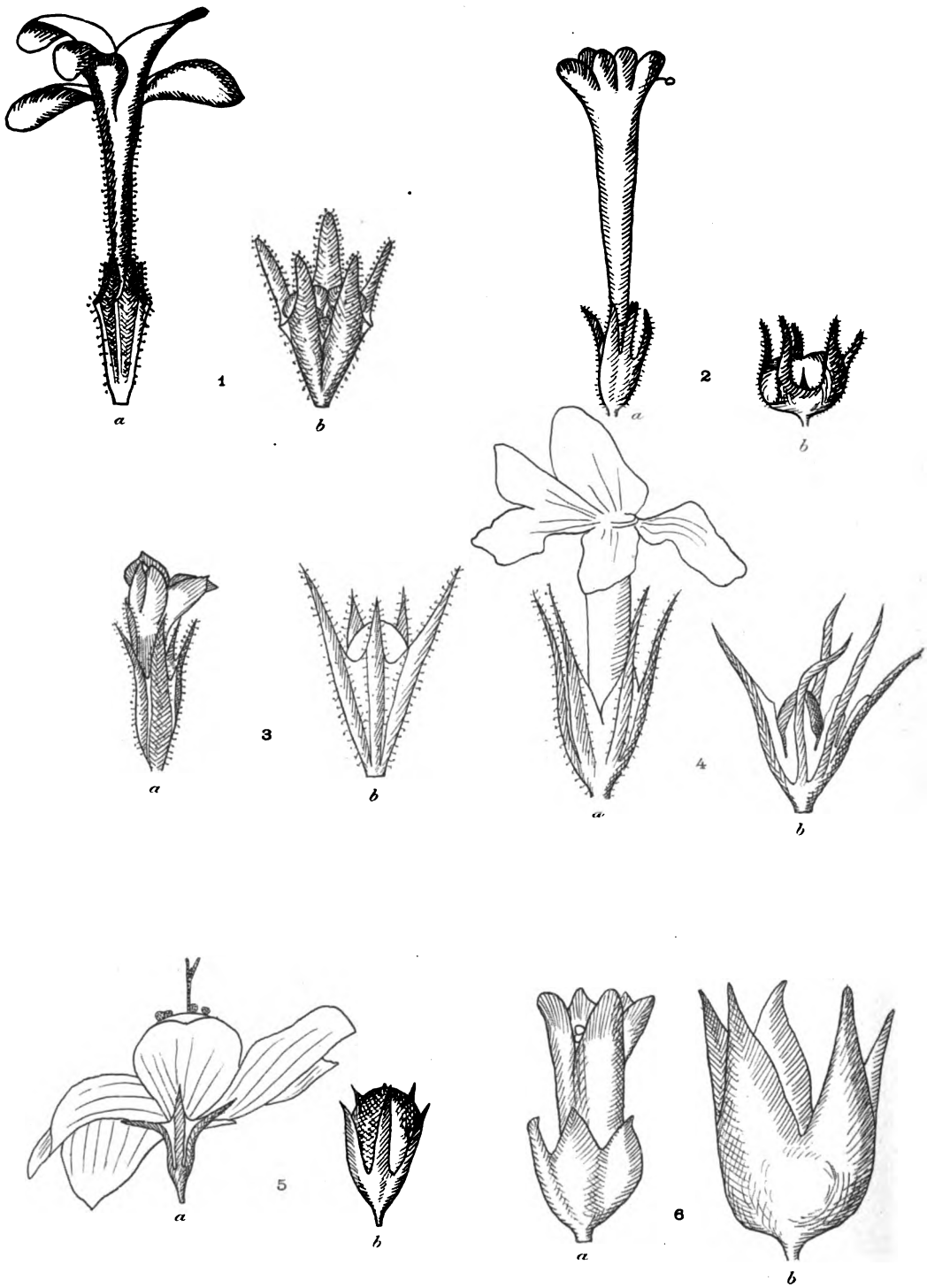

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FLOWER AND FRUIT OF SIX SPECIES.

1. COLLOMIA GRANDIFLORA. 2 GILIA GILIOIDES. 3. NAVARRETIA PUBESCENS.
4. PHLOX AUSTROMONTANA. 5. LINANTHUS LINIFLORUS. 6. POLEMONIUM REPTANS.

a. FLOWER b. FRUIT.

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BOTANY

Vol. 2, pp. 1-71, Pls. 1-11 May 10, 1904

A REVIEW OF CALIFORNIAN POLEMONIACEAE.*

BY

JESSIE MILLIKEN.

INTRODUCTION.

The Polemoniaceae, while clearly defined as a natural order of plants, show unusual complexity of variation within the order. By far the greater number of species belong to the western coast of America, hence coming to the observation of botanists only in comparatively recent years.

The order was first defined by Jussieu in 1789, and called by him Polemonia, including the genera Phlox and Polemonium of Linnaeus, and Cantua and Hoitzia of his own. According to Engler and Prantl, Bentham and Hooker, and De Candolle, the genus Hoitzia is synonymous with Loeselia of Linnaeus, and the latter name has remained for six or seven species of Mexican plants. Phlox, Polemonium and Loeselia, with the two Mexican genera, Cobaea and Bonplandia of Cavanilles, have been considered as acceptable from the time of their naming by the early scientists. As this paper treats only of the California Polemoniaceae, the three genera, Loeselia, Cobaea and Bonplandia, which have no representatives within the state are not considered.

In 1798 an expedition was made from Spain to the western coast of South America, and during their visit to Chili and Peru, two Spanish botanists, Hypolito Ruiz and Joseph Pavon, collected many plants, representing, according to their opinion, one hun-

*Thesis presented in partial fulfilment of the requirements for the degree of Master of Science, University of California, December, 1902. Prepared under the direction of Professor W. L. Jepson.

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dred and thirty new genera. Among these were Gilia and Navarretia. It is with the North American representatives of these Chilian and Peruvian plants and their near relatives that the difficulty of classification in Polemoniaceae has been the greatest. Not only have authors differed much as to the best way to define the genera, but they have had to revise their own work many times as more material and further study demanded.

The next important steps in the history of the order were taken in the early part of the nineteeth century, when the western coast of North America became accessable to collectors. Many new genera were described. Among them, Linanthus of Bentham (1833) is the only one deserving generic rank.

To present the complicated synonomy necessary to give a complete history of the genus Gilia. using this term in the most comprehensive sense that it has as yet been used, namely by Asa Gray, in the Supplement to the "Synoptical Flora of North America" would only lead to confusion. Suffice it to say that many of the genera such as Leptodactylon, Fenzlia, Hugelia and Ipomopsis were named by Hooker, Bentham, Michaux and others, from limited material sent to them from the Pacific Coast, but without knowledge of the abundance of related plants still undiscovered, and of the extent of the field. Many of these genera are conveniently used by Bentham in De Candolle's "Prodromus Systematis Naturalis Regni Vegetabilis," IX, (1845), also by Bentham and Hooker, in "Genera Plantarum," II, (1876), and by Engler and Prantl, in "Die Natürlichen Pflanzenfamilien," IV3A, (1897), as subgenera or sections of Gilia. In the last work the Polemoniaceae are worked up by A. Peter.

The most complete and reliable descriptions of North American Polemoniaceae are those of Asa Gray in the "Synoptical Flora of North America," II, the first edition appearing in 1878 and the second in 1886. Since that was published, however, Edward L. Greene has done much work in the way of partial revision. The basis of his division of the order into genera is to be found in "Pittonia," I, (1887), followed by a treatment of Polemonium, Collomia and Navarretia. In "Pittonia," II, (1892), the genus Linanthus is considered. There are two small genera of his own, Langloisia, including three species,

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L. Matthewsii, L. Schottii and L. setosissima treated in "Pittonia," III (1898), and Microsteris, within which he groups several species which are considered in this paper and are ordinarily accepted as Gilia gracilis, treated in "Pittonia," III. "The Phloxes of Western North America" (1899), is the title of a paper by Elias Nelson, in which the genus Phlox is revised.

There is need at the present time of a general survey of the order to bring together the results of the latest research, and in attempting this, I have made such omissions, additions and changes as seem necessary from my present point of view. The material studied is that of the Herbarium of the University of California, the Herbarium of the California Academy of Sciences, and also various collections made by Dr. W. L. Jepson, H. M. Hall, H. P. Chandler, J. P. Tracy, M. S. Baker, G. B. Grant, and fresh material obtained during the summer of 1902 and 1903.

The genera of the order, excluding those which have no representative species in California, are six:—Polemonium, L., Collomia, Nutt., Navarretia, R. & P., Gilia, R. & P., Linanthus, Benth., and Phlox, L. Several of the characters formerly relied upon in defining these genera have been found to separate species evidently very nearly related and vice versa. Thus, Gray was led to drop the thoroughly good genus Collomia and merge it in Gilia. His judgment would be justified, since the characters chiefly emphasized proved unreliable, if it had not been possible to find other constant characters to replace them, as is shown below. The mucilagenous seeds, characteristic of Collomia, are possessed by many species in all other respects typical of another genus. Examples of this are Gilia aggregata and Gilia filiformis, Linanthus Bigelovii, and many Navarretia species. The declined stamens, and appendaged filaments of Polemonium are also found outside of that genus. For instance, Linanthus liniflorus possesses hairy appendaged filaments, and the stamens of Gilia Matthewsii are conspicuously declined.

As is stated by Greene, in "Pittonia," I, the form of the corolla, the insertion and direction of the stamens, the character and number of the seeds, are all found to be unreliable as primary generic characters. Greene selects as of first value the calyx.

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This is excellent in the case of Collomia and Polemonium, being so reliable that the use of other characters of habit and foliage are almost superfluous.

Taking the order as a whole, Collomia may, in the first place, be well marked off by the turbinate, accrescent calyx, the tube possessing replicate sinuses, and not being distended by the mature capsule. Polemonium is equally distinct with its entirely herbaceous calyx, accrescent, and not distended by the capsule. The other genera cannot be so easily separated by a single character as the foregoing. The pungent, unequally lobed calyx of Navarretia is found to hold with all species agreeing in respect to general habit and foliage. This is true also of Linanthus, but the character of the foliage is necessary to separate some species of this genus from those of Gilia. Still, the cylindrical to urn-shaped calyx, with equal lobes, and conspicuous, broad, hyaline spaces between the ribs, the tube equalling the capsule, but distended, and usually ruptured by the mature fruit, is a primary feature of typical forms. Phlox, to a still greater degree than the last two genera, must be distinguished by the foliage and habit rather than by the calyx, and is the only genus where the form of the corolla is of value. The strictly salver-form corolla with narrow orifice is a constant and, therefore, a reliable character.

After separating the five genera which I have just considered, there still remains a large number of forms, some exceedingly variable and others less so. Looked at superficially, these forms fall into groups which are easily recognized at a glance; but a more careful study shows them to be so intimately related that they must be of one genus. This sixth genus may well take the inclusive name of Gilia, and cover the subgenera corresponding to these unmistakable, but superficial, groups. If connecting links had not been found, these groups would doubtless still be kept as distinct genera, as they were formerly considered.

With the question of genera disposed of, there remains the more difficult task of classifying under each its several species. Leaving considerable latitude for differences of opinion, there are from one hundred and twenty-five to one hundred and seventy-five species on the Pacific side of the Rocky Mountains, and new species are continually being described. It is, therefore, with full

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knowledge of the probable incompleteness, and the possibility of wrong judgment that the list of described species with which this paper concludes is offered. The small number of species of Phlox, Collomia, and Polemonium are comparatively well marked and will cause little trouble to the California botanist, except that, among the Polemoniums, there is much confusion in nomenclature concerning P. humile Willd. and P. humile var. pulchellum Gray, P. viscosum Nutt., and P. parvifolium Nutt. The questions can only be settled by access to type specimens which I have not thus far obtained, and the names are used which seem, from a careful reading of the various references to the subject, to come nearest to the truth. The differences between the Navarretia species are not great, but the small differences, referring chiefly to foliage and corolla, are easily recognized except in a few cases of hybrids. The subgenus Eugilia, of the genus Gilia, includes an almost endless variety of forms, which are, with much generalization, reduced to the species named below. More light would doubtless be thrown upon their relationship by a detailed study of geographical distribution and ecologic conditions.

KEY TO THE GENERA.

I. Calyx growing with the fruit, nearly distended by the capsule.
  A. Calyx wholly herbaceous. 1. POLEMONIUM.
  B. Calyx not wholly herbaceous. 2. COLLOMIA.

II. Calyx growing after the flowering stage, always more or less distended by the capsule, and usually ruptured by it.
  A. Stamens equally, or slightly unequally inserted; corolla variable.
    a. Calyx lobes unequal and pungent; leaves all alternate. 3. NAVARRETIA.
    b. Calyx lobes equal, rarely pungent.
      1. Upper leaves alternate, variable. 4. GILIA.
      2. Leaves usually all opposite and palmately parted. 5. LINANTHUS.
  B. Stamens very unequally inserted; corolla strictly salverform with narrow orifice. 6. PHLOX.

POLEMONIUM, L.

Leaves alternate, pinnatifid; calyx entirely herbaceous, accrescent, and not distended by the mature capsule; filaments more or less declined and hairy at the base.

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KEY TO THE SPECIES.

I. Root perennial.

A. Tall, with few branches from a slender tap root.

a. Corolla pink, large. 1. *P. carneum.*

b. Corolla bright blue. 2. *P. coeruleum.*

B. A span high from a more or less tufted root-stock.

a. Leaves scarious, sheathing, pinnae three-parted, crowded. 3. *P. eximium.*

b. Leaves with entire oblong pinnae two to seven lines long; corolla deep blue with yellow tube. 4. *P. pulchellum.*

c. Leaves with entire pinnae one to one and one-half lines long, nearly as broad; corolla pale blue to white. 5. *P. parvifolium.*

II. Root annual.

a. Flowers solitary in the leaf axils, and scattered. 6. *P. micranthum.*

1. Polemonium carneum Gray.

Perennial, a foot or two high, branching and leafy, soft-pubescent; leaves five to six inches long below, an inch or less long in the inflorescence, many broad- to narrow-lanceolate pinnae averaging an inch in length; inflorescence single or in a terminal corymb of two to four flowers; calyx four to five lines long, campanulate, with broad, rounded base, lobes longer than the tube, lanceolate; corolla campanulate, an inch long, pink fading to purple, tube shorter than the corolla, lobes round-obovate; stamens inserted about half way up on the tube, unequal in length, shorter than the corolla, very pubescent at the base; style about equal to the stamens; capsule round, three to four lines in diameter, included in the tube of the enlarged calyx, seeds three to four in each cell.

San Mateo Co., C. T. Blake, J. B. Davy. Near San Francisco, G. R. Vasey. Woods of Siskiyou Co., E. L. Greene.

2. Polemonium coeruleum L.

Perennial, one to three feet high, erect, simple or with few branches, inflorescence glandular-pubescent, otherwise glabrous; leaves four to eight inches long with many lanceolate pinnae about one inch in length; inflorescence of terminal, rather close panicles or small axillary ones; calyx about three lines long, campanulate, the broad, lanceolate lobes shorter than the tube, often with tinges of purple and red; corolla deep blue, campanulate, little more than twice the calyx, tube shorter than the

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calyx, lobes obovate, slightly crenate; stamens inserted low in the tube, very pubescent, equalling or exceeding the corolla, declined; style much exserted; "ovules ten in each cell." (Jepson.)

Lake Tahoe, W. C. Blasdale. Western slope of Washoe Mts., Nevada Co., J. B. Davy. Sierra Nevada Mts., H. N. Bolander. Bear Valley, San Bernardino Mts., H. M. Hall. Mendocino Co., Dr. A. Kellogg. Mt. Lassen, Plumas Co., Mrs. C. C. Bruce. Sissons, Shasta Co.

Polemonium coeruleum L. is a European plant and Gray considers the American plant to be the same and calls it P. coeruleum. (Syn. Fl. II, 151). Greene thinks the native plants of the Rocky Mountains and the Sierra Nevada Mountains, and even of the Atlantic states, will be found to be distinct and names them P. occidentale. (Pitt. II, 75.)

3. **Polemonium eximium** Greene. *P. confertum* Gray.

Perennial, a span high or less; stems few from a tufted rootstock, glandular-pubescent and viscid, "musky fragrant" (Gray); leaves mostly radical, with dilated, sheathing petioles which are scarious, two to four inches long, cauline few and shorter, pinnae many, one to three lines long, three-parted and near together, leaves subtending the inflorescence one-half inch long with few spatulate pinnae entire or with one lobe; inflorescence large for the plant, a close corymb, or headlike, erect; calyx four lines long, funnelform to almost cylindrical, lobes spatulate, covered with quite long glandular hairs; corolla little more than twice the calyx, tube longer than the limb, lobes roundish-obovate, deep blue to purple; stamens inserted half way up the tube, included, slightly pubescent at the base; style with the large three-lobed stigma shorter than the stamens; "ovules about three in each cell" (Gray).

This California species of Greene differs from P. confertum of the Rocky Mountains in having a perfectly erect inflorescence instead of a slightly declined one, and in having shorter corollas.

Mt. Conness, Tuolumne Co., type locality. Mt. Lyall, Mono Co. Harrison's Pass, King's River, Fresno Co. Mt. Dana, Mono Co., F. P. McLean, 12,000 feet, and at Summit 13,050 feet, H. M. Hall and E. B. Babcock. Mt. Goddard,

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Fresno Co., H. M. Hall and H. P. Chandler. Head of King's River, C. H. Merriam.

4. **Polemonium pulchellum** Bunge. *P. humile var. pulchellum* Gray. *P. moschatum* Wormskiold. *P. humile* Lind. *P. pulcherrimum* Hook.

Perennial, about a span high, from a more or less creeping root-stock, few branches, and these principally from the base, conspicuously glandular-pubescent to glabrous; leaves three to six inches long, pinnae five to fifteen, roundish to oblong-oval, two to seven lines long; inflorescence of rather small loose cymes; calyx two and one-half lines long, campanulate, lobes longer than the tube, broad-lanceolate; corolla twice the calyx, pink to blue, with yellow tube which about equals the calyx, lobes obovate, crenate; stamens inserted near the base of the tube but adnate to the top, dilated and pilose at the base, shorter than the corolla, equal, anthers round; pistil conspicuously exserted.

Marble Mt., Siskiyou Co., H. P. Chandler. Plentiful at Donner Pass, Nevada Co., J. B. Davy. Truckee River Basin. Placer Co., Sierra Nevada Mts., A. M. Carpenter. Meadows near Black Mt., Fresno Co., H. P. Chandler and H. M. Hall.

The plant originally described by Bunge is from central Asia and it is quite probable that our plant of the California mountains is not the same, but it seems impossible now to decide.

5. **Polemonium parvifolium** Nutt. *P. viscosum* (Nutt.) Gray.

Perennial, four to five inches high, from a densely tufted root-stock, with several scaly, short branches bearing closely imbricated leaves at their summits; the flower stems with few and shorter leaves, about twice the length of the basal leaf cluster; the whole plant viscid-pubescent; leaves two to three inches long, leaflets one and one-half lines long or less, nearly as broad, obtuse to broadly acute, at intervals not exceeding their own length; flowers on pedicels not exceeding the corolla, in small groups paniculately arranged; calyx two and one-half lines long, lobes nearly equalling the tube, broad-lanceolate, acutish; corolla twice the calyx, bluish to white; filaments hairy appendaged; style shorter than the lobes.

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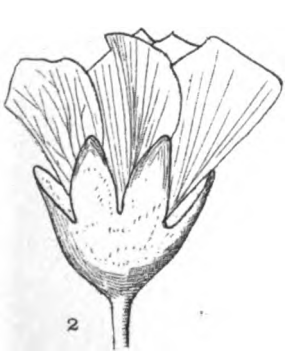

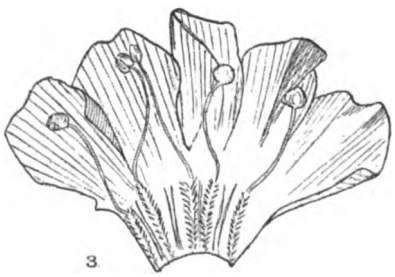

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POLEMONIUM PARVIFOLIUM.

1. ENTIRE PLANT. 2. FLOWER. 3. COROLLA OPENED. 4. PISTIL.

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In 1897 P. A. Rydberg published in the "Torrey Botanical Club Bulletin," XXIV, 252, a result of his study of P. viscosum Nutt. After seeing the type he says it is much nearer related to P. confertum than to P. humile. P. viscosum as described by Gray in the "Synoptical Flora," on the other hand, is near to P. humile and differs from the original description of P. viscosum by Nuttall, especially in the calyx lobes which are elongated-lanceolate according to Nuttall, and this character is excluded by Gray. A specimen in the California Academy of Sciences from near Lassen's Peak, collected by J. G. Lemmon, No. 26, evidently near P. humile and here described, is probably P. parvifolium Nutt. in manuscript.

6. **Polemonium micranthum** Benth. *P. antarcticum* Griseb. ex Benth.

Annual, three to eight inches high, many basal branches diverging but finally erect, viscid-pubescent from the base upward; leaves one inch or less long with five to thirteen small lanceolate pinnae; flowers mostly single in the leaf axils and scattered; calyx open campanulate, the broad lanceolate lobes much longer than the tube; corolla "whitish, almost rotate, a line or two long, shorter than the calyx, filaments almost naked at the base" (Gray); capsule round, ovules two or three in each cell.

Plains of Goose Lake, Mrs. R. M. Austin and Mrs. C. C. Bruce.

COLLOMIA NUTT.

Leaves mostly alternate, the lower sometimes paired, never filiform, palmately parted, not strictly pinnate; calyx turbinate, accrescent, and not distended by the mature capsule, scarious below the sinuses, which are are markedly replicate in age; stamens unequally inserted; seeds usually one, or few in each cell.

KEY TO THE SPECIES.

A. Leaves lanceolate, entire or toothed.

a. Corolla large, salmon-yellow. 1. *C. grandiflora.*

b. Corolla small, lobes purple, one line long; calyx lobes subulate. 2. *C. linearis.*

c. Corolla small, purple, lobes one line long; calyx lobes narrow and distinctly awned. 3. *C. tinctoria*

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d. Corolla larger than the preceding, five to six lines long, limb three to four lines broad, deep blue; calyx lobes subulate. 4. *C. mazama.*

B. Leaves variously lobed and divided. 5. *C. heterophylla.*

1. **Collomia grandiflora** Benth.

Annual, from six inches to two and one-half feet high, simple or with few branches, leafy to the top, roughish-puberulent and glandular-viscid to nearly glabrous; leaves alternate, one to two inches long, and one and one-half to three lines wide, usually entire but rarely with short lobes or teeth, tapering at both ends, without petioles, edges often revolute; bracts broader and shorter than the leaves; inflorescence usually of single terminal bracted cluster, with occasionally smaller lateral clusters; calyx two to four lines long, lobes triangular, shorter than the tube, herbaceous; corolla an inch long, funnelform to salverform, orange colored, tube slender, thrice the calyx; stamens inserted somewhat irregularly above the middle of the tube, of unequal length, some included, others exserted; anthers small, round, blue; capsule equalling the calyx tube in length but not distending it, acute at the base, obtuse at the apex, one seed in each cell.

Common in the mountains throughout the state. (Plate 1.)

2. **Collomia linearis** Nutt. *Gilia linearis* Gray.

Annual, four to twelve inches high, simple or branching, roughish-puberulent; leaves one-half to two inches long, one to four lines wide, entire, tapering at each end, or, above, becoming truly lanceolate, without petioles, edges sometimes revolute; bracts lanceolate, not shorter than the upper leaves; flowers in small terminal clusters, and, on branched specimens, in axillary clusters; calyx three to four lines long, the narrow triangular segments alone herbaceous; corolla only twice the calyx, tube very slender-funnelform, lobes not exceeding 1 line, purple; stamens inserted irregularly and of unequal length in the tube of the corolla; style two lines long, stigmas very short, reaching three-fourths up the tube; one seed in each cell.

San Bernardino Co., H. M. Hall. Fresno Co., H. M. Hall and H. P. Chandler. Truckee, Nevada Co., G. P. Sonne. Deer Park Inn, Placer Co., C. J. Fox, Jr. Bear Valley, Amador

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Co., Geo. Hansen. Pine Creek, Lassen Co., M. S. Baker and F. Nutting. Humboldt Co., J. B. Davy.

3. **Collomia tinctoria** Kellogg. *Gilia aristella* Gray.

Annual, three to eight inches high, branching, puberulent, and more or less glandular; leaves alternate, entire, an inch long more or less, not exceeding two lines in width, tapering at both ends, often into a distinct petiole at the base; inflorescence single, or two to three-flowered when axillary, and three to five flowered when terminal, the one to three bracts like the leaves; calyx three lines long, segments narrow at the base and distinctly awned, as long or longer than the tube; corolla six lines long, funnelform, purple, tube very slender, lobes about one line in length; stamens inserted unequally in the upper part of the tube, and of unequal length, anthers minute, blue; pistil exserted; capsule equalling the tube of the calyx, tapering at the base, one seed in each cell.

Humboldt Co., H. P. Chandler. Cañon Creek, Trinity Co., Alice Eastwood. Sisson, Shasta Co., W. A. Setchell and C. C. Dobie. Summit, Sierra Nevada Mts., A. Kellogg, type specimen.

4. **Collomia mazama** Coville.

Perennial, six to twelve inches high, branches few from a slender root-stock; inflorescence glandular, hairy, below glabrous or nearly so; leaves six to fourteen lines long, lanceolate, tapering at the base, sessile or with slightly margined petioles, the upper entire or crenate, the middle and lower with few subulate teeth toward the apex; bracts similar to the upper leaves; flowers congested in a terminal, rather small head-like cyme, occasionally a very small inflorescence from the axil of an upper leaf; calyx three and one-half to four lines long, lobes subulate, blue-margined, equalling the tube; corolla five to six lines long, deep blue, tube narrow, expanding into the ample limb which is three and one-half to four lines broad; stamens nearly equally inserted in the tube, unequal in length, some much exserted and more or less declined; style also much exserted.

Klamath Co., Oregon, Mrs. A. M. Coombs. Near Crater Lake, Oregon, F. V. Coville and J. B. Leiberg. Described here because likely to be found within California.

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5. **Collomia heterophylla** Hook. *Gilia heretophylla* Gray.

Annual, three to fifteen inches high, branching, puberulent, and somewhat glandular; leaves variously divided and cleft in the same plant, most deeply divided at the base; inflorescence of small, bracted, terminal clusters; bracts broad and exceeding the flowers, entire or notched; calyx with only slightly revolute sinuses in the flowering stage but more revolute in fruit, the very slender acerose lobes exceeding the tube in length; corolla four to six lines long, funnelform, tube dark purple, slender, lobes lighter in color, one and one-half lines long; stamens of unequal lengths, inserted unequally in the tube, anthers round, yellow; pistil about half the length of the corolla; capsule oblong, equalling the tube of the calyx, seeds two or three in each cell.

Lower slopes of Mt. Tamalpais, Marin Co., W. L. Jepson, H. P. Chandler. Howell Mt., Napa County, J. P. Tracy. Mendocino Co., W. L. Jepson. Eureka, Humboldt Co., J. P. Tracy. Jackson, Amador Co., Geo. Hansen.

NAVARRETIA Ruiz & Pavon.

Leaves all alternate, pinnatifid, segments setaceous or spinescent; calyx tube scarious between the prominent angles, not splitting in fruit, segments more or less unequal; stamens equally or subequally inserted. There is much more similarity in the habit of the species of this genus than in any of the others.

KEY TO THE SPECIES.

A. All the leaves lax, bracts more or less so.
- *a*. Prostrate, with radiating branches from beneath the sessile primary inflorescence, which is near the ground. 1. *N. prostrata*.
- *b*. A span high; leaves and bracts long and usually twice pinnatifid; primary flower cluster sessile. 2. *N. leucocephala*.
- *c*. Three inches high or less; leaves few, linear, entire or with few segments, bracts more or less rigid. 3. *N. minima*.
- *d*. Four to fourteen inches high; stems leafy to the top; flowers white, small. 4. *N. cotulaefolia*.
- *e*. Equally tall; flowers larger and yellow. 5. *N. nigellaeformis*.
- *f*. Two to six inches high; inflorescence woolly; bracts rigid and pungent; flowers with yellow tube and purple limb. 6. *N. prolifera*.

B. Leaves as well as bracts rigid and pungent.
- *a*. Leaves sometimes lax at the base, rigid above with acerose pinnae; long retrose white hairs on the stem. 7. *N. intertexta*.

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b. Leaves with expanded blade at the apex, this tapering at each end and bearing small sharp teeth. 8. *N. setiloba.*

c. Upper leaves and bracts twice pinnatifid, pinnae very fine and numerous, appearing netted. 9. *N. tagetina.*

d. Soft-pubescent bracts scarious at the broad base, the many teeth spinescent; seeds one in each cell, or a second aborted one. 10. *N. pubescens.*

e. Viscid-pubescent and noxious scented; bracts broad at the base, divisions extending at various angles. 11. *N. squarrosa.*

f. Viscid but sweet-scented, smaller than the preceding. 12. *N. mellita.*

g. Leaves and bracts broad, entire except for few pinnae at the base. 13. *N. heterodoxa.*

h. Stems slender, wiry; leaves linear, entire except one or two pairs of short pinnae at the base. 14. *N. filicaulis.*

i. Less slender than the last; leaves pinnate below and toothed above, capsule four-angled at the apex. 15. *N. mitracarpa.*

j. Bracts with three to five rigid, acerose, divaricate divisions; flowers in many small heads; corolla shorter than the longest calyx lobes, persistent on the mature capsule. 16. *N. divaricata.*

k. Flowers in loose glomerules; flowers short-pedunculate, corolla yellow. 17. *N. Breweri.*

l. Leaves with linear rachis, bracts dilated, with spinose pinnae, double or triple. 18. *N. subuligera.*

m. Viscid-pubescent; leaves with narrow oblong rachis and few pinnae, bracts considerably dilated; flowers deep blue, large. 19. *N. viscidula.*

n. Viscid; leaves very rigid and more or less coriaceous, lobes wholly spinose. 20. *N. atractyloides.*

o. Leaves very broad, not coriaceous, and lobes not wholly white spinose. 21. *N. foliacea.*

p. More slender than the last, three spinose teeth near the apex of the leaves and bracts, strongly recurved or hooked. 22. *N. hamata.*

1. **Navarretia prostrata** Greene. *Gilia prostrata* Gray. *Navarretia involucrata* R. and P.

Annual, prostrate, with radiating branches making the plant six inches across, glabrous except the inflorescence which is puberulent; leaves and bracts one or two inches long, lax, with narrow strap-shaped rachis, and slender pinnae four or five lines long; primary inflorescence sessile and near the ground, large, radiating branches ending in smaller heads; calyx two lines long, four lobes short and entire, one longer, with one or two teeth, all pungent-tipped; corolla about twice the calyx, slender

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tube yellow, lobes purple; stamens inserted at the sinuses equalling or slightly exceeding the lobes, anthers oval, large in proportion to the flower; pistil about equalling the stamens.

Downey, Southern California, A. Davidson. N. involucrata R. and P. is the South American type, and analogue of N. prostrata, according to Greene.

2. **Navarretia leucocephala** Benth. *Gilia leucocephala* Gray.

Annual, about a span high, simple or branched, glabrous, stems shiny-white; leaves lax, in delicate forms an inch or less long, in more robust forms three and one-half inches, once or twice pinnatifid; inflorescence of terminal heads, the primary one sessile; calyx two to three lines long, slender, lobes acerose, slightly unequal, entire, pungent tips almost awn-like; corolla white, tube very slender, included, limb comparatively broad, lobes nearly two lines long; stamens inserted at or near the sinuses, exserted anthers oblong; pistil much exserted.

Fresno Co., Mariposa Co. Amador Co. Butte Co., Mrs. C. C. Bruce. Lake Co. Solano Co., W. L. Jepson. Mendocino Co.

3. **Navarretia minima** Nutt. *Gilia minima* Gray.

Annual, three inches high or less, often broader than high, finely puberulent to glabrous; leaves few, linear, entire or with few divisions; bracts as long as the leaves, and exceeding the small heads of flowers, more or less rigid; flowers white, minute; calyx tube five-angled, distinct, cylindrical, with firm distended hyaline spaces, lobes shorter than the tube, spinescent, three of them two to three parted, and longer than the other two.

Monterey Co. Placer Co., A. M. Carpenter. Sierra Valley, northern California. Eagle Lake, Lassen Co., M. S. Baker and F. Nutting.

4. **Navarretia cotulaefolia** Hook. and Arn. *Aegochloa cotulaefolia* Benth. *Gilia cotulaefolia* Steudel, also Gray excluding *N. pubescens.*

Annual, four to fourteen inches high, simple or branching, quite robust, puberulent; calyx somewhat ciliate; leaves an inch or two long, lax, twice pinnatifid, pinnae many, with short cuspidate tips; outer floral bracts exceeding the inflorescence which

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is of terminal and axillary heads; calyx four lines long, with four acerose segments, two long and two short or sometimes five parted; corolla five to six lines long, tube white, about equalling the calyx, lobes four or five, obovate to oblong, capsule frequently only two celled; ovules one or two in each cell.

Lake Co. Solano Co. Alameda Co. Two specimens from Lake Co. more lax and leafy than most forms of Navarretia with leaf-like bracts about the head but with large, wholly yellow, funnelform corollas.

5. **Navarretia nigellaeformis** Greene.

Annual, in the habit of N. cotulaefolia but the bracts, if not the leaves, more rigid, heads quite large and much bracted, the bracts compound-pinnatifid, the pinnae white-setaceous-tipped; calyx five lines long, slender, tube obscure, two lobes much exceeding the other three and divided; corolla ample funnelform, bright yellow with five dark purple or red spots in the throat, little exceeding the calyx; capsule two celled, two seeds in each cell.

Butte Co., Mrs. C. C. Bruce. Black's, Yolo Co. Merced City. Willows, Colusa Co., J. B. Davy. Porterville, Tulare Co. Mrs. K. Brandegee. San Miguel, Monterey Co., A. Norton. San Luis Obispo Co., M. M. Miles.

6. **Navarretia prolifera** Greene.

Annual, from two to six inches high, simple or sparsely branched, branches usually starting just beneath the primary inflorescence, almost naked and glabrous; bracts and calyces woolly pubescent, "viscid" (Greene); leaves an inch long or more, filiform, lax, but with setaceous-tipped segments; bracts shorter but with longer segments, rigid and pungent, exceeding the flowers in the small heads; calyx three lines long, with five nearly equal, acerose teeth about equalling the hyaline tube; corolla twice the calyx, tube yellow, expanding into an ample throat, lobes dark purple, one line long; stamens inserted in the upper part of the tube, exserted, but little if at all exceeding the lobes, anthers oval; pistil exceeding the stamens, curving between the lobes; "capsule many seeded" (Greene).

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Amador Co., Mrs. K. Curran, and Tulare Co., T. J. Patterson, whence the types.

7. **Navarretia intertexta** Hook. *Gilia intertexta* Steudel. *Aegochloa intertexta* Benth.

Annual, three inches to one foot in height, simple or branched, usually robust; retrose pubescence on the stem usually dense, white; leaves once or twice pinnatifid, lax at the base, becoming rigid with bristle-like pinnae above, bracts especially rigid with acerose, pungent lobes; inflorescence in terminal heads often quite large, one inch in diameter; calyx three and one-half lines long, with five unequal but entire, stout, very rigid lobes, terminating in white bristles; corolla white, tube exceeding the longest calyx segment, lobes about one to two lines long; stamens and style much exserted. anthers minute, oblong; capsule three-celled and many seeded.

Common through the Sierra Nevada and Coast Range mountains from Shasta Co. to San Diego Co.

8. **Navarretia setiloba** Coville and Funston.

Annual, six inches or less high, branching, viscid-puberulent throughout, with few gland-tipped hairs above; leaves about one inch long, pinnatifid, the pinnae of the lower half of the leaf simple or toothed acerose lobes, spinescent-tipped, those of the upper half small, with sharp teeth on the expanded blade which tapers at both ends; bracts similar except for the expanded, hyaline base, thus leaving a very narrow central portion, bracts exceeding the calyces; calyx four lines long, lobes subequal, rarely toothed, herbaceous except the setaceous tips, about half the tube which is entirely coriaceous; corolla five to six lines long, tube slender, twice the calyx, limb comparatively large, two and one-half to three lines across, purple; capsule shorter than the calyx tube, round at the base, acute at the apex, one seeded(?).

Between Kernville and Havilah, Kern Co., "Death Valley Expedition," Coville and Funston. Templeton, San Luis Obispo Co., J. B. Davy.

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9. **Navarretia tagetina** Greene.

Annual, three to twelve inches high, simple or with few spreading branches, slightly puberulent; leaves few, one-half to one and one-half inches long, the lower lax, once pinnatifid, the rachis and pinnae linear, the upper twice pinnatifid, the secondary pinnae spinescent, terminal primary pinna with many short, acerose teeth or spines, pinnae of the bracts so many and fine as to give a network appearance characteristic of the inflorescence, which is in a terminal head on the nearly bare branch or, in case of primary ones, several clusters together; calyx three lines long, with very irregular lobes, two larger with at least two pair of pinnae, the three smaller with a single lobe near the apex, hyaline portion inconspicuous; corolla purple (or sometimes white?), one-half inch long or less, tube extremely slender, limb comparatively ample, throat and lobes each a line long; capsule transparent, imperfectly obconical, one-celled, with three compressed seeds.

Howell Mountain, Napa Co., and Vacaville, Solano Co., W. L. Jepson. First collected by E. L. Greene in Siskiyou Co., 1876, then near Folsom, 1883, by Mrs. K. Curran.

10. **Navarretia pubescens** Hook. and Arn. *Aegochloa pubescens* Benth. *Gilia pubescens* Steudel. *Gilia cotulaefolia* Gray in part.

Annual, five inches to one foot high, simple or branching, pubescent, not viscid, and not strong-scented(?); leaves an inch or two long, flexuous, with many divisions which are usually subdivided, terminal segment often dilated and toothed, cuspidate but scarsely pungent; bracts rigid, scarious at the broad base, the many teeth spinescent; flowers in quite large heads; calyx five lines long, three lobes shorter, entire or with one tooth, two longer and with several teeth; corolla six lines long, funnelform, tube white at the base, becoming purple as it expands upward, lobes very dark purple, one and one-half lines long; stamens inserted at the sinuses, recurved, not equalling the lobes; pistil straight, nearly equalling the lobes; capsule oblong, equalling the tube of the calyx, usually one seed, sometimes two, or one and an aborted second.

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Common in hill country Mariposa Co. to Modoc Co., and in Coast Range Mts. in Contra Costa, Solano, and Lake Cos. (Plates 1 and 3.)

11. **Navarretia squarrosa** Hook and Arn. *Hoitzia squarrosa* Eschscholtz. *Aegochloa pungens* Benth. *Gilia pungens* Hook., Bot. Mag. t. 2977. *Navarretia pungens* Hook., Fl. Bor. Am. ii 75. *Gilia squarrosa* Gray.

Annual, a few inches to two feet high, simple or branched, very viscid-pubescent and noxious-scented; leaves one and one-half inches long or less, twice pinnatifid, pinnae extending in various angles, very rigid and pungent but herbaceous; inflorescence large and round; calyx of five narrow-lanceolate, herbaceous ribs, scarcely united by the hyaline portion, slightly irregular in length, all entire, five lines long; corolla equalling the calyx, funnelform to salverform with quite ample throat; lobes light or dark blue, one and one-half lines long; stamens inserted near the base of the tube, unequal in length and slightly so in insertion, not equalling the tube; pistil also included; capsule oblong, pitted, many seeded.

Common on roadsides and fields from Monterey Co. north to Washington. (Plate 3.)

12. **Navarretia mellita** Greene. *Gilia mellita* Greene.

Annual, about a span high, branching, often diffusely so, making the plant broader than high, pubescent and "sweet scented" (Greene); leaves one and one-fourth inches long at the base, smaller upward, once or twice pinnatifid, rachis and terminal segment expanded in the upper leaves and bracts, all rigid and pungent; inflorescence of many small heads; calyx two and one-half lines long, lobes five, entire and nearly equal, the hyaline portion firm even in fruit; corolla minute, pale; stamens and pistil included in the tube; capsule oval, coat very thin, many seeded.

Central California, common. Solano Co., W. L. Jepson. Napa Co., E. L. Greene. Marin Co., Mrs. K. Brandegee. Monterey Co., H. P. Chandler.

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PHOTO LITHOGRAPHY

NAVARRETIA SQUARROSA.

1. ENTIRE PLANT. 2. COROLLA. 3. COROLLA OPENED.

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13. **Navarretia heterodoxa** Greene. *Gilia heterodoxa* Greene. *Gilia viscidula* var. *heterodoxa* Gray.

Annual, nearly a foot high and much branched, puberulent, "clammy" (Greene); leaves an inch long or less and quite broad, bracts as broad as long or nearly so, all the foliage pinnatifid at the base and nearly entire upward, the lobes spinescent; flowers in many small heads; calyx two lines long in flower, lobes extremely slender, equal, pungent, the tube split by the mature capsule; corolla five lines long, not conspicuous, lobes narrow, blue, stamens exserted and declined; capsule one line long, oval, very thin walled, fourteen-seeded.

Calistoga, Napa Co., E. L. Greene. Howell Mt., Napa Co., W. L. Jepson. New Almaden, Santa Clara Co., J. B. Davy.

14. **Navarretia filicaulis** Greene. *Gilia filicaulis* Torr.

Annual, four to eight inches high, branching, stems and branches slender, slightly puberulent but scarcely clammy; leaves an inch or two long near the base, smaller upward, all filiform, entire or with a pair or two of short filiform pinnae at the very base; bracts dilated at the base; flowers in numerous small heads, on leafy peduncles one-half inch long or more, with the long spine-like ends of the bracts exceeding the flowers; calyx one and one-half lines long, teeth unequal in length and breadth, one much exceeding the others in both dimensions, and two very small, all entire; corolla two and one-half lines long, dark purple; stamens and pistil much exserted, nearly twice the corolla, stigmas long; capsule thin walled, one-celled or imperfectly two-celled, with four to eight seeds.

Mariposa Co., J. W. Congdon. Gwin Mine, Calaveras Co., W. L. Jepson. Colfax, Placer Co., E. L. Greene. Forest Ranch, Butte Co., Mrs. C. C. Bruce.

15. **Navarretia mitracarpa** Greene.

Annual, nearly related to N. filicaulis but not so slender, somewhat glandular-viscid; leaves pinnatifid below and toothed toward the apex; calyx two and one-half lines long, tube rigidly funnelform, lobes longer than the tube, three of them toothed, the other two smaller and entire; corolla four and one-half to six

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lines long, funnelform, limb two lines long, lobes and throat about equal, usually with dark spots at the base of the lobes; stamens exserted, declined in age; capsule acute at the base where the dehiscence begins, continuing half way up, the more obtuse apex prominently four angled, one-seeded.

Colusa and Lake Cos., Mrs. K. Curran. Knoxville grade to Lower Lake, Lake Co., W. L. Jepson.

16. **Navarretia divaricata** Greene. *Gilia divaricata* Torr. in Gray. Proc. Am. Acad. viii, 270.

Annual, two to four inches high, usually branching into a plant as broad as high, branches slender, sparsely puberulent, bracts white-pubescent; leaves few, less than one inch long, entire or with few lax divisions, with very short, white-cuspidate tips; bracts with three to five rigid, acerose, sharp-pointed, divaricate divisions, equalling or exceeding the flowers; inflorescence of many small heads; some heads almost sessile, others on very long leafless peduncles; calyx two and one-half lines long, lobes entire, acerose, almost awned; corolla minute, exceeded by the longer calyx lobes, tubular, one-half line long, light purplish blue, tube persistent about the mature capsule; stamens and pistil included in the tube; capsule not firm when mature, enclosed by the corolla tube, seeds three to six in each cell.

Sierra Nevada Mts. at 6000 to 7000 feet altitude, Modoc Co. to Fresno Co.

17. **Navarretia Breweri** Greene.

Annual, two to four inches high, branching, stems finely puberulent; leaves with linear rachis and long acerose pungent pinnae, foliage also very finely puberulent; flowers in rather loose glomerules, short pedunculate; calyx three and one-half lines long, lobes straight, entire, twice the tube, slightly unequal; corolla yellow, not exceeding the calyx; stamens longer than the corolla; capsule slightly exceeding the calyx tube, oblong, two seeds in each cell.

Big Valley, Modoc Co., M. S. Baker and F. Nutting. Prosser Creek, near Truckee, Nevada Co., C. F. Sonne.

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18. **Navarretia subuligera** Greene.

Annual, three or four inches high, nearly simple and but slightly puberulent; leaves nearly an inch long with linear rachis, four or five pair of acerose pinnae, the terminal one long, rigid, bracts with broader rachis, sometimes ovate dilated, pinnae spinose, very rigid, usually double, divided to the base, or two- or three-parted; calyx three lines long, two lobes much longer and broader than the other three; corolla tube equalling the calyx, limb small, exserted.

Type, Amador Co., M. R. Curran in the California Academy of Sciences.

19. **Navarretia viscidula** Benth. *Gilia viscidula* Gray.

Annual, from one to eight inches high, usually branching, pubescent, sometimes viscid; leaves an inch or two long, slender but not lax, becoming broader upward, rachis serrated, or divided into short, setaceous pinnae; bracts considerably dilated in some cases; flowers in medium sized terminal heads; calyx three to three and one-half lines long, segments lanceolate, all setaceous, two of them toothed, the rest entire; corolla twice the calyx, tube exceeding the calyx lobes by one-half line, gradually expanding into quite an ample, yellow throat, lobes broad ovate, two lines long, purple; stamens inserted in the sinuses, about equalling the corolla, anthers purple; pistil equalling the stamens; capsule "normally three to six seeded" (Greene).

Common in the hills of Napa, Solano, Marin Cos., and south to San Diego Co.

20. **Navarretia atractyloides** Hook. and Arn. *Aegochloa atractyloides* Benth. *Gilia atractyloides* Steud.

Annual, one to eight inches high, the larger forms diffusely branching, puberulent and "viscid heavy scented" (Greene); herbage often purplish; leaves ovate-lanceolate to linear-lanceolate in outline, coriaceous and very rigid, with several long entirely spinose teeth; flowers in small terminal and axillary clusters, hardly capitate; calyx three lines long, lobes five, unequal, entire or toothed, tube obscure; corolla four to five lines long, dark purple, open-funnelform, limb comparatively ample; stamens

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inserted in the upper part of the tube, nearly equalling the lobes, anthers oval, blue; stigma included.

Valleys of central and Southern California, and on Santa Catalina Island. "Hybridizing with N. viscidula and N. pubescens in the San Joaquin Valley" (Greene).

21. **Navarretia foliacea** Greene.

Annual; leaves very broad, foliaceous, not coriaceous but very rigid, pinnae not wholly spinescent but herbaceous at the base; corollas white, small.

Monterey Co. to San Diego Co. Claremont, Los Angeles Co., H. P. Chandler. Clay soil, mesas, San Bernardino Co., S. B. Parish. Witch Creek, San Diego Co., R. D. Alderson.

22. **Navarretia hamata** Greene.

Annual, four to eight inches high, rather slender and diffusely branching, very rigid, glandular-pubescent, "aromatic" (Greene); leaves mostly with nearly linear rachis and several spinose teeth, the upper three teeth more or less recurved, the terminal one often hooked, bracts broad, foliaceous, and spinescent-lobed; flowers in many small terminal clusters and few smaller axillary ones; calyx segments erect, spinose-tipped, one or two with a few teeth; corolla five to six lines long, salverform, narrow tube considerably exserted, lobes one and one-half lines long, the whole deep purple and proportionately large; stamens and stigma included in the tube; capsule globular, small, not smooth, seeds about twelve, minute, angular.

Monterey Co. to San Diego Co. Monterey Co., H. P. Chandler, No. 378.

GILIA, RUIZ & PAVON.

Leaves mostly alternate, either entire or pinnately lobed, or toothed; calyx split by the mature capsule even when somewhat accrescent, scarious below the sinuses, segments equal; corolla not strictly salverform; stamens equally inserted.

This genus is more variable than the others in general habit and there are exceptions to many of the characters, such as the alternate leaves, the equality of the insertion of the stamens, and,

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in G. multicaulis and related species, the calyx grows considerably with the fruit, and may not be split by it. In the subgenus Aegochloa there is irregularity in the corolla.

KEY TO THE SPECIES.

A. Subgenus **Microsteria.**—Leafy to the top; flowers in pairs or a few in a cluster; corolla tubular-funnelform, not exceeding one-half inch.

a. Leaves all entire, lower opposite; flowers in pairs on unequal pedicels. 1. *G. gracilis.*

b. Leaves all entire; plant not exceeding three inches; flowers two to several in a cluster; calyx densely white-pubescent. 2. *G. depressa.*

c. Leaves alternate, variously lobed and divided; flowers in small clusters, corolla purple, tubular-funnelform. with very small lobes. 3. *G. gilioides.*

d. Leaves alternate, variously lobed and divided; corolla white, salverform to funnelform, limb as broad as long, equalling the tube. 4. *G. Traskiae.*

B. Subgenus **Eugilia.**—Larger leaves at the base, becoming inconspicuous and bract-like toward the top; flowers single in an open panicle.

a. Base leaves once or twice pinnatifid, with narrow rachis; corolla tube rarely exceeding the calyx, throat and lobes broad and short. 5. *G. latiflora.*

b. Leaves nearly one inch broad, ovate-spatulate with dentate margins. 6. *G. latifolia.*

c. Base leaves usually twice pinnatifid, with narrow rachis, pedicels mostly shorter than the flowers; corolla funnelform, tube slender, attenuated. 7. *G. tenuiflora.*

d. Leaves mostly entire, less than one line wide; corolla dark purple. 8. *G. leptalea.*

e. Leaves all entire, filiform; corolla yellow. 9. *G. filiformis.*

f. Leaves mostly entire, not concentrated at the base; corolla white. 10. *G. capillaris.*

g. Leaves in basal cluster, strap-shaped with few teeth; corolla large, funnelform, dark purple. 11. *G. Davyi.*

h. Leaves in basal cluster, strap-shaped with few teeth; corolla minute. 12. *G. leptomeria.*

i. Leaves in basal cluster, once or twice pinnatifid, corolla about twice the calyx, white to purple. 13. *G. inconspicua.*

j. Even the upper leaves pinnatifid; corolla tube yellow, lobes deep blue. 14. *G. diffusa.*

k. Base leaves once pinnatifid, pinnae obtusish; corolla yellow, tubular-funnelform. 15. *G. ochroleuca.*

C. Subgenus **Capitata**—Leaves twice or thrice pinnately divided into linear divisions, not concentrated at the base; flowers in more or less dense clusters on naked peduncles.

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a. Inflorescence of small loose clusters; calyx mainly herbaceous; corolla tube yellow, throat ample with dark purple markings, lobes pale purple to pinkish. 16. *G. tricolor.*

b. Inflorescence of small loose clusters; calyx mainly herbaceous; corolla with dark spots at the base of the lobes; plant small and glandular. 17. *G. millifoliata.*

c. Inflorescence of terminal and axillary clusters, few-flowered; calyx mainly herbaceous; corolla tubular-funnelform, lobes only one line long. 18. *G. Nevinii.*

d. Inflorescence a panicle, and flowers solitary on long and short peduncles. 19. *G. peduncularis.*

e. Inflorescence of loose head-like clusters; calyx almost entirely herbaceous; corolla less than one-half inch long, dark blue. 20. *G. multicaulis.*

f. Inflorescence of large, rather loose clusters; calyx mainly hyaline; corolla one-half to three-fourths inch long, funnelform with abrupt dilation. 21. *G. abrotanifolia.*

g. Inflorescence of dense heads; calyx as broad as long, chiefly hyaline; corolla bright blue, throat abruptly dilated; stamens much exserted. 22. *G. Chamissonis.*

h. Inflorescence large conglomerate clusters, more or less woolly-pubescent; corolla throat very abruptly dilated, ample, pale, lobes blue; stamens little exserted. 23. *achilleaefolia.*

i. Inflorescence small, capitate; corolla light blue to white, throat abruptly dilated but not ample, lobes slender; stamens white, much exserted. 24. *G. staminea.*

j. Inflorescence small, capitate; corolla light blue, slender throughout; stamens equal to or shorter than the lobes. 25. *G. capitata.*

D. Subgenus **Ipomopsis.**—Biennial; inflorescence thyrsoid-paniculate; flowers yellow to red, showy. 26. *G. aggregata.*

E. Subgenus **Elaphocera.**—Biennial or short-lived perennial, woolly; leaves short and pinnatifid, pinnae and rachis broad and lax; flowers capitate-congested. 27. *G. congesta.*

F. Subgenus **Hugelia.**—Erect and rigid, white-woolly at least when young; leaves narrow-linear with few linear divisions; stamens always exserted, anthers sagittate.

a. Root perennial, stems woody; leaves rigid with few very short divisions; inflorescence large. 28. *G. densifolia.*

b. Root annual or biennial; leaves less rigid with few lax divisions; inflorescence small scattered clusters. 29. *G. virgata.*

c. Annual; leaves mostly entire and filiform; flowers solitary or two to three in a cluster, white with narrow dark spots in the throat. 30. *G. sparsiflora.*

d. Annual; corolla sulphur-yellow. 31. *G. lutescens.*

G. Subgenus **Leptodactylon.**—Phlox-like, rigid perennials, with alternate three-parted leaves, more or less fascicled in the axils.

a. Two to five feet high; corolla salverform, more than one inch long with nearly equal breadth of limb. 32. *G. Californica.*

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b. Plant not exceeding two feet; corolla funnelform, not exceeding one inch. 33. *G. pungens.*

H. Subgenus **Langloisia.**—Rigid low annuals of the desert; leaves pinnately divided, some of the pinnae reduced to bristles; flowers scattered, solitary, without bracts; calyx tube splitting to the base.

a. Leaves with narrow rachis enlarging gradually toward the apex; corolla bilabiate.

1. Corolla only slightly irregular, lobes much shorter than the tube. 34. *G. Schottii.*
2. Corolla very irregular, lobes equalling the tube. 35. *G. Matthewsii.*

b. Leaves abruptly dilated at the apex; corolla regular. 36. *G. setosissima.*

1. **Gilia gracilis** Hook. *Collomia gracilis* Dougl. *Phlox gracilis* Greene.

A variable annual, an inch to a span high, simple or diffusely branching, entirely covered with fine pubescence and some glandular hairs; leaves all entire, opposite below, becoming alternate above, averaging an inch in length and two to three lines in width; inflorescence mostly two-flowered in the axils, flowers on equal pedicels; calyx three to four lines long, very slender, ribs closely approximated in the flowering stage, slender lobes equalling or exceeding the tube; corolla usually very slightly exceeding the calyx by the tiny spreading limb, tube very slender, equalling the calyx or slightly exceeding it, white or yellow, limb rotate, dark blue or purple; stamens unequally inserted above the center of the tube, filaments very short, anthers narrowly oblong; capsule round to oval, seeds one in each cell.

From San Diego Co. to Modoc Co., both in the Sierra Nevada Mts. and the Coast Ranges.

2. **Gilia depressa** M. E. Jones.

Annual, one to three inches high, branched, roughish pubescent; leaves few, alternate, linear to narrow-lanceolate, mucronate-tipped, bracts broader lanceolate, but more acute, and cuspidate-tipped; inflorescence with two to several flowers in a cluster; calyx about two lines long, very densely white-pubescent, lobes acerose, very acute, almost awned, recurved, nearly

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equalling the tube; corolla white, little exceeding the calyx lobes, oval, short; "stamens inserted above the middle of the tube and slightly exserted" (Gray); capsule oval, shorter than the calyx, "seeds in each cell four to five" (Gray), two in each cell in specimens from Dry Lake near Rabbit Springs, Mojave Desert, collected by S. B. and W. F. Parish.

Argus Mts., Inyo Co., C. A. Purpus.

3. **Gilia gilioides** Greene. *Collomia gilioides* Benth. *Gilia glutinosa* Gray. *Gilia divaricata* Nutt.

Annual, four inches to two feet high, pubescent, with long white hairs at right angles to the stem, glutinous, usually branching; leaves variable, from a few lines to three inches in length, entire to three-parted, or pinnatifid, with several pairs of pinnae, divisions broad-lanceolate, to narrowly linear; inflorescence single or two- to three-flowered, subsessile and bracted, or on quite long pedicels; calyx about three lines long, slender, lobes acerose, equalling the tube, hairy; corolla tubular, twice or more than twice the calyx, white to purple, lobes very short, not spreading; stamens irregularly inserted in the tube, filaments sometimes equalling the tube, anthers round, blue; stigma blue, included; capsule globular, splitting the calyx, one seed in each cell.

Los Angeles Co., A. Davidson. Modoc Co., M. S. Baker. At intervening stations in the Sierra Nevada and Coast Range Mts. (Plate 1.)

4. **Gilia Traskiae** Eastwood, MSS.

Annual, a span to a foot high, branching; stems and inflorescence very glandular-viscid, foliage less so; leaves a few lines to three inches in length, variously toothed, lobed or divided, usually pinnatifid, the pinnae with few teeth or lobes, lobes obtusish and mucronate-tipped; flowers solitary or in small clusters, sessile or on pedicels shorter than, or twice the length of the corolla; calyx one to two lines long, open-funnelform to campanulate, broadish, lobes green, longer than the tube which is almost entirely herbaceous; corolla white, salverform to funnelform, narrow tube not longer than the calyx, limb equal-

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ling the tube and as broad as long; stamens protruding just beyond the throat, anthers large, blue; capsule globular, slightly exceeding the calyx tube, splitting it.

Nearly related to G. gilioides, differing in the open calyx and salverform corolla with the broad limb equalling the tube. Santa Catalina Island, collected by Mrs. Blanche Trask, May, 1896 and May, 1897, the latter the type. Also collected by T. S. Brandegee on the island, May, 1891.

5. **Gilia latiflora** Gray. *Gilia tenuiflora var. latiflora* Gray.

Annual, a span to fifteen inches high, branching, nearly glabrous below, glandular above; leaves mostly basal, an inch or two long, once pinnatifid, rachis narrow linear, lobes of about the same width, three to five lines long; upper leaves becoming entire and bract-like; inflorescence a loose panicle, pedicels usually shorter than the flower; calyx one to two lines long in fruit, scarious between the ribs, lobes very short, triangular, sometimes growing to equal the capsule, again much shorter, finally splitting at the sinuses; corolla four to six lines long, tube included, or very little exceeding the calyx, abruptly dilating into the ample throat which is yellow below and purple above, sometimes yellow with purple markings, lobes obovate, purple to white; stamens inserted in the sinuses, filaments very short, anthers round; stigma equalling the lobes of the corolla; capsule short, oval, many seeded.

San Bernardino, San Jacinto, San Antonio and Santa Ana Mts., Southern California. Modoc Co., Mrs. C. C. Bruce. (Plate 4.)

Var. **exilis** Gray. More slender than the species, many flowers on capillary pedicels an inch or more long; corolla small.

San Jacinto Mt., 5000 feet. Not uncommon through the Southern California mountains.

6. **Gilia latifolia** S. Watson.

Annual, four to eight inches high, branching but not profusely; glandular-viscid throughout; leaves one to three inches long, sometimes limited to the base of the plant, broadly ovate spatulate, tapering into a short petiole or sessile, margins

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dentate, teeth prominent, spinose prolongations of the veins of the blade; inflorescence a loose panicle, with minute setaceous bracts; calyx two and one-half lines long, with rounded base, and cylindrical tube, lobes nearly or quite as long as the tube, setaceous; corolla funnelform, about three lines long, "light pink" (Watson), proper tube one line long, throat one and one-half lines, lobes ovate, acute, one and one-half lines long; stamens inserted at the top of the tube, unequal, anthers oblong, those of the longest filaments slightly exceeding the throat; style included; capsule equalling the calyx, distending it and finally splitting the hyaline tube; seeds many in each cell, black.

In deserts near Keeler, Inyo Co., Coville and Funston. Owens Valley, Inyo Co., G. P. Rixford. Waterman's, Mojave Desert, San Bernardino Co., Mrs. K. Brandegee.

7. **Gilia tenuiflora** Benth.

Annual, a span to twenty inches tall, slender with simple stem and loosely, paniculately branching inflorescence, glabrous or nearly so below, glandular upward; largest leaves toward the base, one to three inches long, often in a single basal cluster, rachis very narrowly linear, bipinnatifid; inflorescence a loose panicle, pedicels from very short to eight lines long, slender; calyx not exceeding two lines in the flowering stage, white-scarious between the ribs, lobes shorter than the tube, acute, somewhat accrescent but never equalling the mature capsule; corolla four lines to one inch long, slender-funnelform, tube purple in the upper part, very slender, long-exserted, gradually enlarging into the pale yellow throat, lobes ovate with broadly acute apex; filaments inserted just below the sinuses, about half as long as the lobes, anthers round; stigmas equalling the lobes; capsule oblong, two to four lines long with many seeds.

Menifee, Riverside Co., Alice King. Bear Valley, San Bernardino Co., S. B. Parish. Elsewhere in Southern California and as far north as Monterey Co.

Var. **altissima** Parish. A high altitude variety, very slender, with conspicuous black tack-glands on the pedicels of the inflorescence.

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Aliso Cañon and Mt. Gleason Summit, Los Angeles Co., J. H. Barber. San Jacinto Mt., Riverside Co., 5250 feet, H. M. Hall. Foothills near San Bernardino, Parish.

Var. **Purpusii.** Between *G. latiflora* and *G. tenuiflora;* a span high; leaves and lower stem white-woolly, the upper branches and the inflorescence pubescent with black gland-tipped, short hairs; calyx one and one-half lines long, white, hyaline spaces replicate in flower; corolla "pink" (C. A. Purpus), throat appearing yellow, three-fourths inch long, the tube fully six lines long and perfectly cylindrical, abruptly expanding into the very short throat, lobes two lines long, narrow-ovate; stamens and pistil equalling the corolla.

Openings in groves of Pinus Jeffreyi, Mount Hockett Meadows, Tulare Co., C. A. Purpus. Indicated as a species by Miss Eastwood in the Herb. of the California Academy of Sciences.

8. **Gilia leptalea** Green. *Collomia leptalea* Gray.

Annual, from a few inches to a foot high, nearly glabrous to slightly glandular-pubescent, branching in an effuse panicle; leaves usually entire, an inch long at the base of the stem becoming bract-like upward, very narrow, less than one line wide; flowers solitary on capillary pedicels from two lines to one inch in length; calyx one to two lines long, slender, almost cylindrical, ribs and lobes often blue; corolla dark reddish, at least with reddish purple markings in the throat, from one-third to three-fourths inch in length, slender-funnel-form, proper tube equalling the calyx, throat two to three lines long and lobes as long as the throat; stamens unequal, some included, some exserted; style included; capsule ovate, about equalling the calyx, seeds three in each cell.

Sierra Nevada Mts., from Shasta and Lassen Cos. south to Fresno Co. Wawona, Mariposa Co., Alice Eastwood. Yosemite Valley, W. Brown. Lake Tahoe, S. L. Berry. Baker's Camp, Trinity Co., Alice Eastwood. Humboldt Co., Chesnut and Drew. Pine Ridge, Fresno Co., H. M. Hall and H. P. Chandler.

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9. **Gilia filiformis** Parry.

Annual, a span high or less, effusely branched, nearly glabrous, a few glands; leaves all entire and filiform, an inch long or less, the lower opposite, the upper mostly alternate; flowers solitary, scattered, on filiform pedicels varying from one line to one and one-half inches; calyx one to two lines long, open-campanulate in the flower but closing about the capsule, tube almost none, lobes narrowly subulate; corolla twice the calyx, yellow, campanulate, tube short, lobes notched, oblong, truncate; stamens and style very short; capsule oval, equal to the calyx, seeds several (?).

Panamint Mts., Southern California, "Death Valley Expedition," Coville and Funston, 1891.

10. **Gilia capillaris** Kellogg.

Annual, a span to a foot high, branched, branches typically ascending; glandular and slightly viscid; leaves an inch or less long and one to three lines wide, mostly entire, not concentrated at the base; flowers solitary, pedicels usually not longer than the flowers; calyx one to two lines long, slender in the flower, lobes somewhat recurved; corolla white or white and purple, twice the calyx, tubular-funnelform, lobes a line or less long; stamens included in the tube, anthers round, "blue" (Kellogg); style also included; capsule oval, nearly equalling the calyx lobes, seeds three in each cell.

Red Mt., Mendocino Co., Alice Eastwood. Below Silver Lake, Amador Co., Geo. Hansen. Siskiyou Co., Mrs. K. Brandegee. Modoc Co., Mrs. R. M. Austin. Same place, M. S. Baker and F. Nutting. Placer Co., C. F. Sonne. Same place, A. M. Carpenter.

11. **Gilia Davyi.**

Annual, a span to one foot high, branching from the base or with simple stem and bracteate and branched inflorescence; glandular-pubescent above, glabrous at the base; leaves principally in a basal cluster, an inch or two long, with strap-shaped rachis two to three and one-half lines broad, saliently toothed, teeth broad, cuspidate tipped; flowers scattered, pedicels

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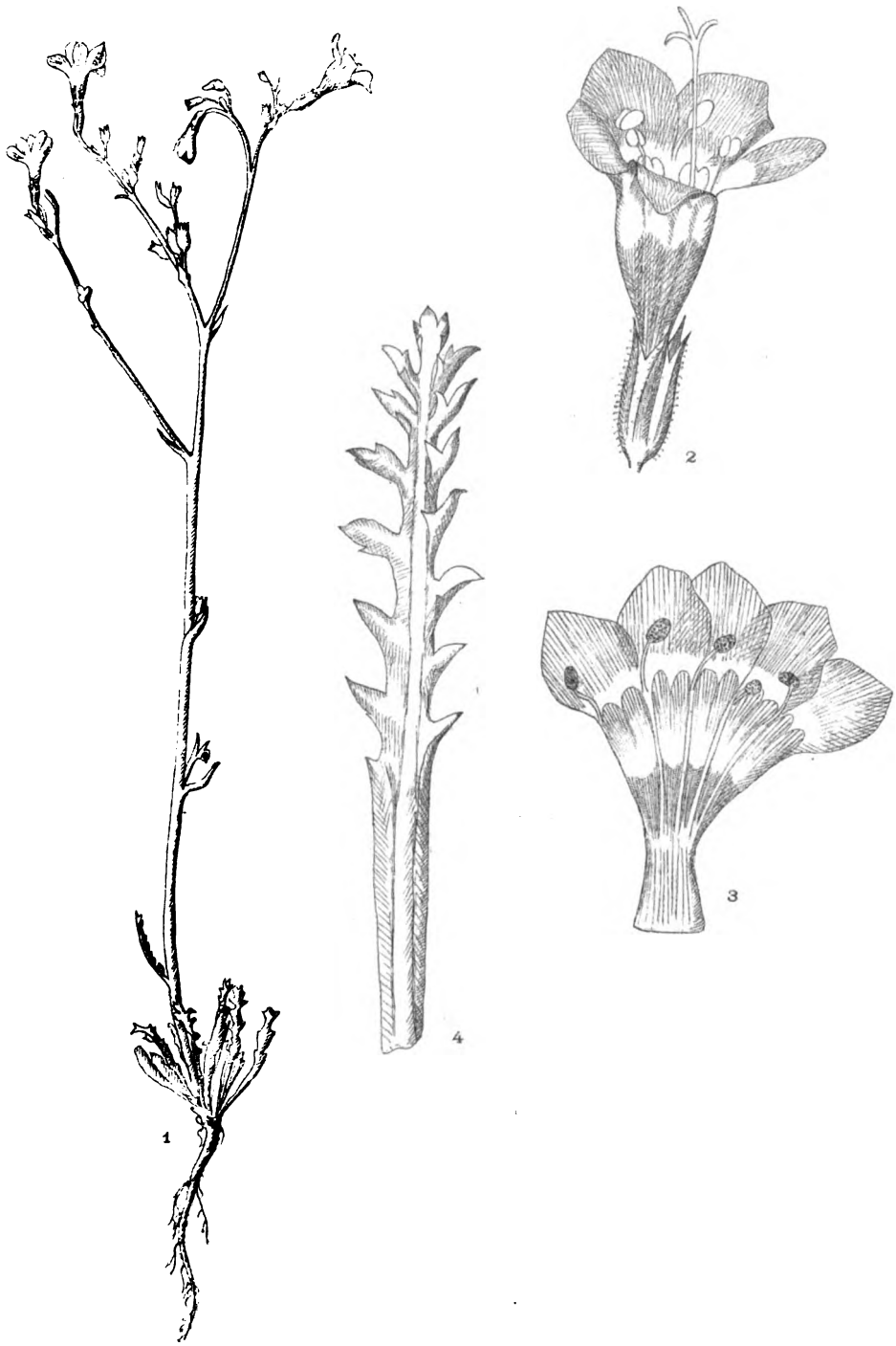

PHOTO LITH BRUTT IN & REGOLY

GILIA DAVYI.

1. ENTIRE PLANT. 2. FLOWER. 3. COROLLA OPENED. 4. BASAL LEAF.

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not exceeding one inch, usually not exceeding the calyx; flowers sometimes fragrant, calyx two to three lines long, lobes short, scarious spaces between the ribs conspicuous; calyx becoming larger in fruit, the lobes equalling the capsule, but finally splitting at the sinuses; corolla usually one-half inch long or more, tube cylindrical, yellow at the base and purple at the top, little or much exceeding the calyx, ample throat purple at the base, white at the top with yellow markings, lobes broad, ovate, purple; stamens inserted in the sinuses, about one-half as long as the lobes, anthers round, yellow; stigmas purple, nearly equalling the lobes; capsule three to four lines long, smaller at the apex than at the base, pitted seeds many in each cell.

Antelope Valley, Southern California, J. B. Davy, No. 2178. Winchester, Riverside Co., H. M. Hall. The type specimen is in the Herb. of the University of California, collected by Mr. Davy and named by him to indicate its fragrance which character does not prove to be constant. (Plate 5).

12. **Gilia leptomeria** Gray.

Coming between G. Davyi and G. inconspicua is this rare California species, with strap-shaped, toothed leaves similar to G. Davyi and very small corollas usually less exserted and with smaller lobes than G. inconspicua.

Kingman, Arizona, N. Wilson. Type locality, mountain valleys of Nevada and Utah. Byrne's Spring, San Bernardino Co., S. B. Parish.

13. **Gilia inconspicua** Dougl.

Annual, a span to two feet high, branching profusely from the base, or with one straight stem branching into a bracted inflorescence; stems glabrous below, leaves slightly puberulent, stems of the inflorescence minutely glandular; leaves one to two and one-half inches long at the base of the stem, pinnatifid and the pinnae three to eight lines long, usually again pinnatifid or toothed; flowers loosely panicled, pedicels not exceeding one inch, usually much shorter; calyx one to two lines long in the flower, lobes equal to or shorter than the tube, scarious between the ribs, in age very slightly accrescent, usually

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only one-half as long as the capsule, finally splitting at the sinuses; corolla three to four lines long, funnelform, from white to purple, with yellow throat, tube included or slightly exserted, lobes roundish with broadly acute apex; stamens inserted almost in the sinuses, filaments very short, anthers round; stigmas equal to or exceeding the lobes; capsule oval to oblong, many seeded.

San Bernardino Co., S. B. and W. F. Parish. Colorado Desert, San Diego Co., W. G. Wright.

Var. **sinuata** Gray. Flowers two or three times as large as those of the species, the tube considerably exserted.

Strawberry Valley, San Jacinto Mts., Riverside Co., H. M. Hall.

14. **Gilia diffusa** Congdon.

From the meager material at hand this species cannot be accurately described. It appears to be nearly related to *G. inconspicua*, but is smaller, more diffusely branching, and even the upper leaves are pinnately divided into linear segments; corolla at least twice the calyx, yellow below and deep blue above.

New Coulterville Road, Mariposa Co., J. W. Congdon. See original description, Erythea, VII, 186.

15. **Gilia ochroleuca** Jones.

Annual, about one span high, branching cymosely above, glabrous except the glandular pubescence on the base of the pedicels; leaves mostly basal, becoming small and bract-like upward, pinnatifid, pinnae obtusish; inflorescence of very loose cymes, pedicels capillary, about six lines long; calyx tubular, one line long, white hyaline spaces conspicuous, lobes minute, subulate; corolla yellow, tubular-funnelform, about twice the calyx (two lines long), lobes with five broad, triangular teeth; stamens and style included; capsule equalling the calyx, splitting it, "seeds developing mucilage and spirieles * * * differing thus from G. micromeria of Gray, also in the glandular pedicels, and funnelform, tubular, and longer corolla" (Jones).

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Growing in sand on Darwin Mesa, Inyo Co. Argus Mts., Inyo Co., at 5000 feet altitude. Erskine Creek, Desert Region of Southern California, C. A. Purpus.

16. **Gilia tricolor** Benth.

Annual, a span to one foot high, puberulent, simple, or branching; leaves an inch or two long at the base, becoming smaller upward, once or twice pinnatifid, rachis and divisions very slender and lax; inflorescence of small clusters of few flowers or single; calyx two to four lines long in flower, mainly herbaceous, margins of the broad ribs often dark blue or purple, lobes acute, equal to or shorter than the tube, slightly accrescent in fruit, but nearly equalled by the capsule; corolla six to eight lines long, salverform, tube short, included, yellow, throat large, yellow with very dark purple markings, lobes broad ovate, pink to purple; stamens inserted at the sinuses, filaments about one line long, anthers oval; capsule oblong, nearly equalling the calyx, seeds many.

Foothills of the Coast Ranges from Shasta Co. to San Luis Obispo Co. Foothills of the Sierra Nevada Mts. from Shasta Co. to Tulare Co. Mojave Desert, Los Angeles Co., according to A. Davidson. Marysville Buttes, Sutter Co., W. L. Jepson. Elk Grove, Sacramento Co., E. R. Drew.

17. **Gilia millefoliata** Fisch. and Mey.

Annual, three to eight inches high, simple or with few branches, glandular-viscid; leaves once or twice pinnatifid, with many narrow pinnae; inflorescence one to few-flowered; calyx mainly herbaceous; corolla four to five lines long, funnelform, with dark markings in the throat; running into G. multicaulis.

Humboldt Co., H. P. Chandler, and southward all along the coast to Monterey Co.

18. **Gilia Nevinii** Gray.

Annual, from two inches to one foot high, simple or branching, glandular-pubescent, often canescent, making the foliage very gray; leaves crowded at the base, typically thrice pinnately divided, the pinnae and rachis very narrow; inflorescence of terminal or axillary clusters of few flowers, on few-bracted

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peduncles; calyx two to three lines long, in flower, mainly herbaceous, hyaline spaces very narrow, lobes shorter than the tube, triangular-subulate; corolla tubular-funnelform, bright blue to purple, twice the calyx, lobes only one line long, not spreading; stamens and style included; capsule about equalling the calyx tube, many-seeded.

Islands off the coast of California and Lower California. Guadalupe Island, F. Franceschi, winters of 1892 and 1893.

19. **Gilia peduncularis** Eastwood in herb.

Closely related to G. multicaulis but much more slender and lower, usually much branched, glabrous below; inflorescence a loose panicle, slightly pubescent, flowers solitary on slender pedicels varying from three lines to six inches; calyx lobes slender, subulate, as long as the tube; corolla broad-funnelform, blue with white tube, little exceeding the calyx; stamens included.

Dutard's Ranch and Olano Creek, near the boundary between Santa Barbara and San Luis Obispo Cos. Alice Eastwood, the former the type. Santa Margarita.

20. **Gilia multicaulis** Benth. *G. achilleaefolia* Lindl.

Annual, four inches to three feet high, branching profusely from the base or simple, puberulent, especially the inflorescence, which is also glandular; leaves once or twice pinnatifid, an inch or two long at the base, cauline leaves sometimes large, usually becoming small and simple, all soft and lax; inflorescence of small terminal clusters, never a compact head, sometimes single-flowered; pedicels usually evident, especially in fruit; calyx two to three and one-half lines long in flower, mainly herbaceous, cylindrical lobes equalling or shorter than the tube, erect, finally growing to exceed the capsule in length but distended and finally splitting at the sinuses; corolla three to seven lines long, twice or thrice the calyx, open-funnelform to salverform, tube included, throat and lobes broad, dark blue or purple; stamens inserted in the throat, equalling or shorter than the lobes; stigmas exserted; capsule oblong, many-seeded.

In the foothills throughout western California. (Plate 4.)

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Var. **detonsa** Gray. A depauperate form from dry hills and poor soil, glomerule more loosely three- to five-flowered or only one.

Found small and one-flowered in the Berkeley hills, Alameda Co., in the same square yard with large five-flowered forms. San Luis Obispo Co., Mrs. R. W. Summers.

Var. **eximia.** Annual, six inches to one foot high, pubescence white-woolly on the petioles, close and long on the calyces; calyx three lines long, quite broad, herbaceous ribs projecting beyond the tube in lanceolate acute lobes one line long, spaces between purple to red, hyaline, conspicuous; corolla tube one and one-half lines long, white, throat two lines long, open-funnelform, lobes two lines long, ovate, somewhat acute, they and the throat deep purple.

Evergreen, Santa Clara Co., J. B. Davy, 1883. San Luis Obispo Co., Mrs. R. W. Summers, 1892.

Var. **alba.** Annual, in general habit like delicate forms of G. multicaulis but differing in the following respects: entire plant glabrous; calyx distinctly hyaline between the ribs; corolla pure white throughout, tubular-funnelform, and but slightly exceeding the calyx.

Type, Los Gatos, Santa Clara Co., A. L. Jaggar.

21. **Gilia abrotanifolia** Nutt., Erythea, iii, 104.

Annual, tall, glabrous, or glandular-pubescent, with few branches or simple; leaves bi- and tri-pinnately dissected; inflorescence large, a rather open cluster, on a long naked peduncle; calyx mainly hyaline, only the ribs and lobes herbaceous, long and narrow; corrolla deep blue, half to three-quarter-inch long and funnelform, not abruptly dilated; lobes oblong; stamens shorter than, or equalling the corolla lobes; style often much exserted; capsule long-oblong.

Claremont, Los Angeles Co., H. P. Chandler. San Luis Obispo Co., Mrs. Blochman. Not uncommon in Southern California.

22. **Gilia Chamissonis** Greene.

Annual, a span to two feet high, simple or branched, glabrous or puberulent; inflorescence on long naked peduncles in crowded

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terminal clusters; leaves large at the base of the stem, two to three and a half inches long, bi- or tri-pinnatifid, rachis and divisions all slender, linear; calyx one and a half to two lines long, nearly as broad in the middle, the tips short-pointed, connivent before and after flowering, tube mainly hyaline, ribs often blue or purple instead of green; corolla deep blue throughout, twice or thrice the calyx, throat broad, abruptly dilating from the cylindrical tube, but not as conspicuously so as in G. achilleaefolia; stamens inserted in the sinuses, much exserted, anthers yellow; stigmas short but much exserted.

San Francisco Bay region, and south to Monterey Co. on the sandy coasts. Above Copperopolis, Calaveras Co., J. B. Davy approaching G. staminea.

23. **Gilia achilleaefolia** Benth.

Annual, a span to two feet high, branching or simple, glabrous or nearly so, except the inflorescence which is more or less densely white-woolly; leaves two or three inches long at the base of the stem, bipinnatifid, upper leaves smaller and once pinnatifid; inflorescence terminal on long naked peduncles, a dense cymose cluster, not strictly a head, often elongated; calyx two to three lines long, mainly hyaline, lobes short-triangular, very acute, not accrescent in fruit; corolla with a cylindrical tube one to two lines long, white, throat very abruptly dilated, short and broad, lobes broad and spreading, blue; stamens inserted at the sinuses but slightly exserted, anthers yellow; stigmas long and exserted; capsule round or oval, several-seeded.

San Diego Co. to San Joaquin Co. in the foothills, not on the sandy coast. This is G. achilleaefolia Benth. according to J. D. Hooker, "Botanical Magazine," t. 5939; not G. achilleaefolia Benth. according to W. J. Hooker, "Botanical Magazine," t. 3440 which is Gray's G. multicaulis, also Greene's. (Plate 4.)

24. **Gilia staminea** Greene.

Annual, a foot or so tall, rather slender, not at all glandular, but the arachnoid pubescence sparse on the petioles and dense on the calyces, otherwise glabrous; inflorescence capitate congested; calyx small, mainly hyaline; corolla pale blue, throat

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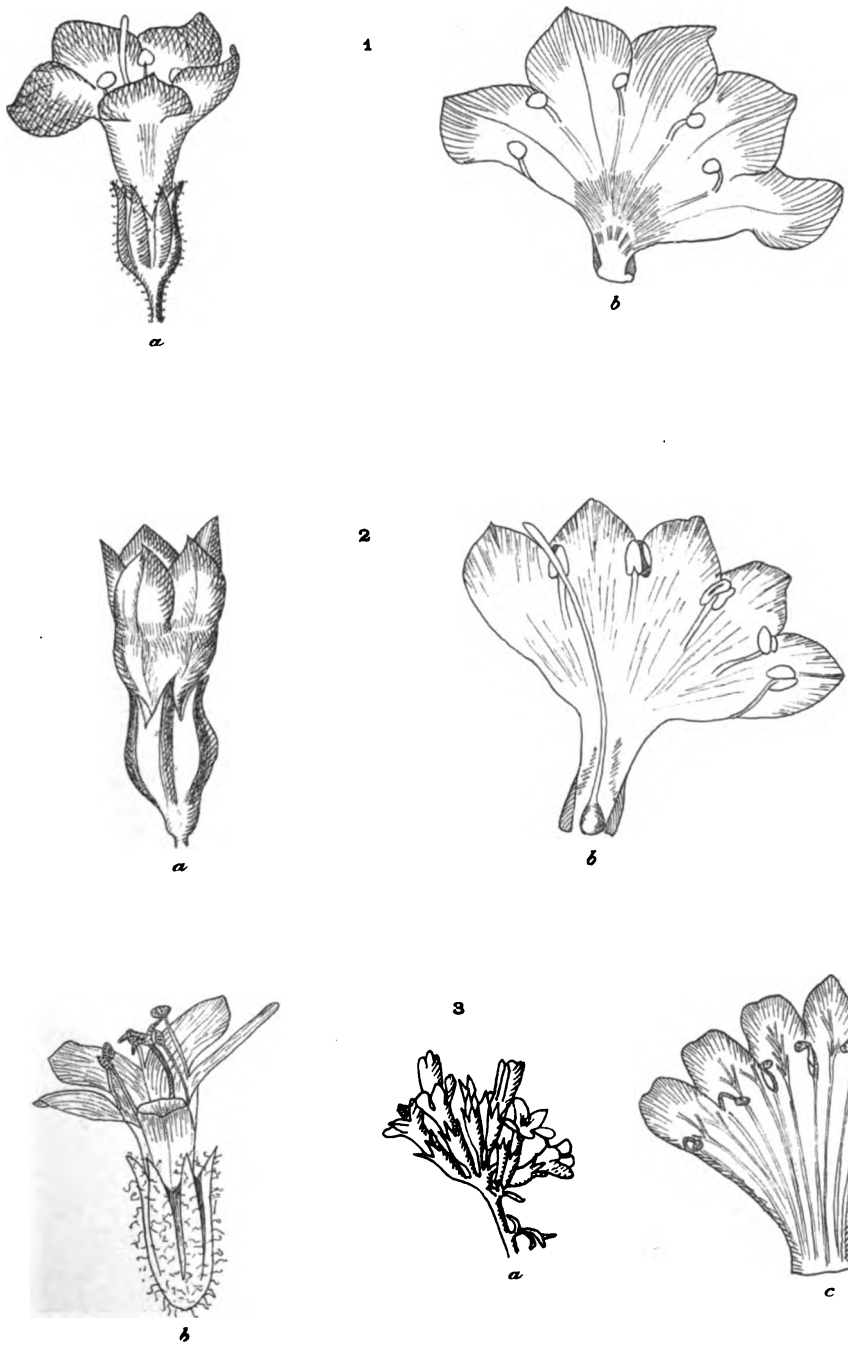

1. GILIA LATIFLORA.
   a. ENTIRE FLOWER.
   b. COROLLA OPENED.

2. GILIA ACHILLEAEFOLIA.
   a. ENTIRE FLOWER.
   b. COROLLA OPENED.

3 GILIA MULTICAULIS.
   a. INFLORESCENCE.
   b. ENTIRE FLOWER.
   c. COROLLA OPENED.

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abruptly dilated but not ample as in G. achilleaefolia and lobes nearly as narrow as in G. capitata; stamens much exserted, anthers nearly white; style also exserted.

Nashville, El Dorado Co., G. P. Rixford. Common in the interior, from Mariposa Co. to Shasta Co.

In Muhlenbergia I, No. 3, Heller describes a new species, Gilia pallida, the type found at the Petrified Forest, Sonoma Co. It seems to be nearest G. staminea.

25. **Gilia capitata** Dougl.

Annual, a span to two feet high, slender, branching, nearly glabrous; leaves once or twice pinnatifid, segments narrow; inflorescence usually in round heads, not large, without woolly pubescence, peduncles long, naked, or with one or two very small bract-like leaves; calyx one and a half to two lines long, slender, hyaline portion between the ribs broad and white, lobes equalling or exceeding the tube; corolla pale blue to white, about twice the calyx, tube nearly equalling the limb, throat not abruptly dilated, lobes narrow, oblong, truncate; stamens pale blue, inserted in the sinuses, exserted slightly beyond the lobes.

Low grounds, Bay of San Francisco to Oregon. Not in the Sierra Nevada Mts.

26. **Gilia aggregata** Spreng. *Cantua aggregata* Pursh.

Annual, one to two feet tall, erect, usually simple with a long terminal compound raceme, stem leafy, especially at the base; leaves sometimes rosetted; often a woolly pubescence on the stem and leaves; calyx more or less glandular; leaves one to two and one-half inches long, once pinnatifid, rarely divided at the base, pinnae few or many, long, and very abruptly acute; inflorescence of large profuse racemes, pedicels short or none; calyx two to three lines long, two lines broad, tube cup-shaped to funnelform, lobes lanceolate, longer or shorter than the tube; corolla one to two inches long, narrow-funnelform with spreading limb, tube not over three lines broad at the top, lobes half as long as the tube, very slender, acute, or shorter and broader, yellow and bright red, often blotched; stamens of unequal lengths, inserted a little below the sinuses, usually exceeding the tube but not equal to the lobes.

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Siskiyou and Modoc Cos. and south in the Sierra Nevada Mts. to Inyo Co.

Var. **Bridgesii** Gray. A small low form with few ascending branches as if from a perennial root; leaves small and lobes obtuse; flowers bright red.

Yosemite, Mariposa Co., Alice Eastwood. Bear Creek, Fresno Co., H. M. Hall and H. P. Chandler.

27. **Gilia congesta** Hook.

Annual, about a span high, branching from the base, branches sometimes so short that it appears matted, more or less woolly-pubescent; leaves three-fourths inch long or less, once or twice pinnately parted, but not at the base, often appearing palmately parted at the apex into three or five divisions, each about the same in width as the rachis; inflorescence crowded in large heads or in smaller heads arranged in a cyme, with long peduncles; calyx one and one-half to two lines long, open-funnelform, mainly hyaline, only the very short acute lobes truly herbaceous, white-woolly; corolla white, three lines long, salverform, tube two lines long and one-half to three-fourths line broad, throat not distinguishable, lobes broad ovate, one line long; stamens inserted at the sinuses, filaments capillary and very short, anthers oval; stigma short, about equalling the stamens; capsule smooth, oval, not equalling the calyx.

Marble Head, Siskiyou Co. Pine Creek, Lassen Co., M. S. Baker and F. Nutting. Modoc Co., M. S. Baker. Shasta Co. and north into Oregon, and south in the higher Sierra Nevada Mts. to Placer Co.

28. **Gilia densifolia** Benth. *Hugelia densifolia* Benth.

Root perennial; plant often woody above the root, usually with many long branches from the base, leafy to the top; leaves rigid, averaging one inch, usually ascending, occasionally recurved with one or more pairs of short rigid acerose divisions; inflorescence of large dense terminal-bracted clusters, slightly floccose-woolly; calyx about three lines long, slender, woolly, two lobes exceeding the other three, all acerose and pungent-tipped, hyaline portion between the ribs very delicate and easily split,

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making the tube of uncertain size; corolla eight lines long or more, tubular-funnelform, tube six lines long, slender, pink to pale purple, lobes about two lines long, oblong, deeper in color than the tube; stamens inserted just below the sinuses, not exceeding the lobes, anthers sagittate, linear, a line long; capsule two lines long, angular, tapering slightly at both ends, seeds two to three in each cell, flat, and white-margined.

San Luis Obispo Co. to San Diego Co.

Var. **sanctora.** Corolla fourteen to fifteen lines long and proportionately ample.

Santa Ana River near Riverside, Southern California, H. M. Hall, No. 683.

29. **Gilia virgata** Steudel. *Hugelia virgata* Benth.

Annual, a span to a foot high, usually branching regularly from every node, the lower branches more often lacking than the upper, the branches rebranched, nearly glabrous except the inflorescence which is more or less floccose-woolly; leaves alternate, narrowly linear, three to fourteen lines long, sometimes entire but usually with one pair of pinnae at the base, long or short but lax, and the whole leaf more often recurved than ascending; flowers sometimes single but usually in small clusters; calyx three and one-half lines long, narrow, lobes of unequal length, extremely slender, and pungent-tipped, tube distended in fruit but not splitting, thus resembling Navarretia; corolla six to seven lines long, funnelform, tube included or slightly exserted, throat ample, yellow, lobes ovate, bright purplish blue beyond the yellow base; stamens inserted at the base of the throat, filaments long, often exceeding the lobes, anthers linear-sagittate, one line long; capsule oblong, tapering at both ends, two seeds in each cell not white-margined.

Mountains throughout the state and plains of Southern California.

Var. **filifolia**. *G. filifolia* Nutt. Small form, flowers very small and slightly exceeding the calyx, lobes often only a line in length.

Lake Co. and Lassen Co.

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Var. **floribunda** Gray. Large, dense, floccose heads of large, well exserted flowers.

Corral Hollow, Brewer, and elsewhere in the South Coast Ranges.

Var. **floccosa.** *G. floccosa* Gray. Lower and more profusely branching than the species; corolla not such a bright, clear blue; stamens inserted just below the sinuses or lower, anthers about one-half line long.

A possible species but running in so closely to G. virgata that the characters are not distinct. Found in the mountains with G. virgata and at lower levels, also eastward into Nevada and Arizona.

30. **Gilia sparsiflora** Eastwood.

Annual, a span to fifteen inches high, slender branches above from the axils of distant alternate leaves, stems very minutely glandular-pubescent, below glabrous; leaves few, averaging one inch in length, with recurved margins, thus appearing filiform, usually entire, occasionally with a pair of short pinnae near the base, these and the main segment cuspidate-tipped, bracts like the leaves but smaller; inflorescence solitary and pediceled when axillary, a cluster of two to three flowers when terminal on the main stem, and subsessile; calyx three to four lines long, densely white-woolly, lobes aristate-subulate, longer than the tube, very slightly unequal; corolla four to five and one-half lines long, funnelform, white with narrow dark spots in the throat, lobes elliptical, about two lines long; stamens protruding through the throat but no more, anthers a line long, narrowly sagittate, white; capsule oblong, nearly equalling the calyx, "seeds few, oblique at the base, three sides generally with rounded angles, developing mucilage and spiricles" (Alice Eastwood).

Collected by Alice Eastwood in King's River Cañon in July, 1899, and also along Bubb's Creek Trail.

31. **Gilia lutescens** Steud. *Hugelia lutea* Benth.

Annual, four to eight inches high, with few branches in the specimens studied, nearly glabrous below, densely white-woolly in the inflorescence; leaves six to fourteen lines long, narrowly

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linear, entire below, usually three-parted near the inflorescence which is congested in small heads at and near the ends of branches; calyx two to three lines long, slender, hyaline, tube very thin, lobes shorter than the tube, ending in delicate white bristles; corolla sulphur-yellow, tube usually included, one and one-half to two and one-half lines long, lobes ovate to oblong; stamens about equalling the corolla or slightly exserted, anthers narrow-linear, nearly one line long.

Mountains north of San Luis Obispo, J. G. Lemmon. Soledad, Monterey Co., Mrs. K. Brandegee. Jolon, Monterey Co., Alice Eastwood.

32. **Gilia Californica** Benth. *Leptodactylon Californicum* Hook. and Arn.

Shrubby perennial, at times reaching four feet in height, branches, bracts and calyces puberulent; leaves glabrous, palmately parted into three to five divisions, rigid, cuspidate-tipped, two to three lines long, more or less fascicled in the axils, and crowded on the stem, alternate; inflorescence single and borne near the ends of branches and closely massed; calyx four to six lines long, slender, ribs strong, and projecting in pungent acerose lobes about half the tube, hyaline portion well marked as in Linanthus; corolla twelve to fifteen lines long, salverform tube exceeding the calyx, sometimes twice its length, throat very short, lobes large, obovate, the whole pink to purple; stamens inserted on the tube above the middle, filaments short, anthers long-oblong; style almost none, stigmas one and one-half lines long, at the very base of the tube; capsule exceeding the tube of the calyx but not its lobes, rounded at the base, smaller at the apex, walls very firm, cells many-seeded.

In the mountains from San Luis Obispo Co. to San Diego Co. A very viscid form with longer leaves is found near Los Angeles.

33. **Gilia pungens** Benth. *G. pungens* and *G. Hookeri* Benth. *G. pungens* var. *caespitosa*, and var. *squarrosa* Gray.

Perennial, often matted so as to resemble Phlox Douglasii or taller, with long branches, glandular-viscid, pubescent to nearly glabrous; leaves three-parted to the middle or a little more, three

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to eight lines long, erect, or spreading when long, segments linear-acerose, often recurved, pungent, much crowded on the stem or one-half inch apart, but usually obscuring the stem, rarely fascicled in the axils; inflorescence loosely clustered toward the summit of the branches; calyx three to six lines long, very slender, herbaceous ribs extending into acerose, pungent lobes about one-half the length of the tube, hyaline portion between the ribs revolute or distended, resembling Linanthus; corolla nine to fourteen lines long, funnelform, tube sometimes shorter than the calyx but more often considerably exserted, lobes as long as the tube, narrow and truncate, not spreading; stamens equally inserted near the top of the tube, filaments not more than one line long, anthers oblong; style one line long, stigmas the same length; capsule oblong, tapering at both ends, about equalling the tube of the calyx; seeds several.

San Bernardino and San Jacinto Mts., and elsewhere in Southern California at high elevations, from 8500 to 11,500 feet. Sierra Nevada Mts., at similar elevations (Mt. Goddard, above Yosemite, Bear Valley, and northward).

Var. **Hookeri** Gray. Perennial, growing taller than the species, not matted; leaves not more than one-half inch long, the middle division twice the lateral ones, rigid, acerose, especially the lower leaves fascicled in the axils, covered with white pubescence, which is sometimes in tiny tufts, herbage blue-green while that of the species is green; flowers not restricted to the summits of the branches.

Found at lower levels than the species, 6500 to 8300 feet, in the mountains of Southern California. Also in the Sierra Nevada Mts., eastern Oregon and Arizona.

Var. **Hallii**. *Gilia Hallii* Parish. Perennial, flowering branches about one foot long; some of the leaves opposite, becoming alternate at the summit, much fascicled, palmately three-parted, divisions very pungent, acerose, the middle one twice or thrice the lateral ones; flowers less than one inch long, loosely clustered at the summit of the branches or terminating the branchlets half way down the main stem; corolla lobes oblanceolate; stamens nearly sessile.

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Type, Coyote Cañon, El Toro Mt., Riverside Co., 5000 feet, H. M. Hall.

Var. **tenuiloba**. *Gilia tenuiloba* Parish. Perennial, flowering branches six inches long; leaves alternate, palmately three-parted, much less rigid than the foregoing variety; flowers solitary and terminal, one inch long or more, light yellow; lobes of the corolla narrow-strap-shaped; anthers on filaments about their own length, one-half line long.

Type, San Jacinto Mt., Riverside Co., S. B. Parish. Seven Oaks, San Bernardino Co., Mr. and Mrs. Grout.

34. **Gilia Schottii** Watson. *G. setosissima var. exigua* Gray. *Navarretia Schottii* Torr. *Loeselia Schottii* Gray. *Langloisia Schottii* Greene.

Annual, two to six inches high, broader than high, with several depressed branches, roughish-puberulent, stems white, herbage grayish; leaves broad at the apex, gradually tapering to a narrower base, or nearly of the same width throughout, pinnatifid, but the pinnae reduced to long white bristles except for a few small lobes ending in bristles; inflorescence scattered or slightly congested; calyx two to two and one-half lines long, lobes ending in long bristles, exceeding the tube, hyaline portion narrow, splitting in fruit; corolla slightly bilabiate, three and one-half lines long, white, tube two and one-half lines long, one-half line broad, cylindrical, throat almost none, lobes narrow, acute; stamens inserted in the upper part of the tube, hardly exceeding it; capsule strongly three-angled, equalling the calyx exclusive of the bristles, seeds five in each cell, small, not white-margined.

Palm Springs, desert base of San Jacinto Mt., Riverside Co., 500 to 700 feet; and elsewhere in the Colorado Desert region of Southern California.

35. **Gilia Matthewsii** Gray. *Loeselia Matthewsii* Gray. *Langloisia Matthewsii* Greene.

Annual, an inch to a span high, branched, more or less matted, stems and foliage densely pubescent or nearly glabrous; leaves about one inch long, narrow, pinnately divided, the lower pinnae reduced to long white bristles, the upper ending in bris-

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tles, leaves dilated at the apex, but not abruptly so; inflorescence scattered or slightly congested; calyx two to two and one-half lines long; corolla tube two and one-half to three lines long, one-half line wide, cylindrical, throat small, limb strongly bilabiate, lobes narrow, dentate, purple, or white, streaked with purple or red; stamens strongly incurved, much exserted; seeds eleven to twelve.

Near Dry Lake, Rosamond, Kern Co., J. B. Davy. Smith Mt., Riverside Co., H. M. Hall. Distributed as G. Schottii from Inyo Co. by Dr. Matthews, 1871; Mohave Desert by Palmer, Lemmon, Parish, Pringle. Near Newhall by Nevin.

36. **Gilia setosissima** Gray. *Navarretia setosissima* Torr. and Gray. *Navarretia Schottii* Torr. *Gilia Schottii* Watson. *Langloisia setosissima* Greene.

Annual, an inch or two high, branching into a mat, slightly roughish-puberulent; leaves one-half inch long, abruptly dilated at the apex which is three-lobed, pinnately divided below, the pinnae reduced to long white bristles usually double; calyx four and one-half lines long, including the bristles; corolla six to nine lines long, white, tube four to six lines long and three-fourths line wide, throat almost none, lobes three to four lines long, oblanceolate, acutish; stamens inserted in the upper part of the tube, reaching half way up the lobes, erect, anthers oblong.

An early and depauperate plant from the deserts of southeastern California, western Arizona and southern Utah, first collected by Coulter.

One specimen from Arizona, N. C. Wilson. It will therefore probably be found in the desert region of Southern California.

LINANTHUS BENTH.

Leaves opposite and palmately parted, or rarely entire and linear; calyx with well marked hyaline spaces between the herbaceous ribs, which are prolonged into five equal lobes; flowers solitary or in terminal clusters or heads; stamens equally inserted and usually of equal length; seeds usually many in each cell.

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KEY TO THE SPECIES.

A. Dichotomously branched without scabrous pubescence; flowers sessile or subsessile.

a. Not glandular; corolla limb one inch broad. 1. *L. dichotomus*.

b. Not glandular; corolla much smaller. 2. *L. Bigelovii*.

c. Glandular pubescence on calyx. 3. *L. Jonesii*.

d. Soft-pubescent throughout; flowers large with very short tube, and toothed or fringed margins. 4. *L. dianthiflorus*.

B. Less dichotomous; leaves scabrous-pubescent; flowers on capillary or filiform pedicels.

a. Corolla five to six lines long, broad-funnelform to rotate, white, often with blue lines; pilose ring at the base of the filaments. 5. *L. liniflorus*.

b. Corolla three lines long, campanulate, exceeding the calyx by two lines. 6. *L. filipes*.

c. Corolla smaller; calyx extremely narrow with acute base. 7. *L. pusillus*.

d. Corolla minute, not exceeding one and one-half lines, broader than the last; capsule one-seeded. 8. *L. Harknessii*.

e. Corolla tube equalling or slightly exceeding the calyx, limb salverform. 9. *L. Bolanderi*.

f. Corolla one-half inch long, tube equal to the calyx or slightly exserted, expanding into an ample, dark purple throat. 10. *L. ambiguus*.

g. Corolla one-half inch long, tube much exserted. 11. *L. Rattani*.

C. Not dichotomously branched; flowers not on capillary pedicels nor in heads.

a. Corolla one-half to three-fourths inch long, tube very short with a conspicuous appendage at the base of each lobe. 12. *L. Parryae*.

b. Corolla smaller, no appendages. 13. *L. demissus*.

c. Corolla tube six to seven lines long. 14. *L. Pacificus*.

d. Corolla twice the calyx, tube one-half line long, no appendages. 15. *L. concinnus*.

e. Corolla golden yellow. 16. *L. aureus*.

D. Perennials.

a. Flowers in small heads, sessile or subsessile; leaves with broad linear segments. 17. *L. Nuttallii*.

b. Flowers less crowded, pediceled; leaves with narrower segments. 18. *L. floribundus*.

E. Flowers in bracteate heads, sessile, with corolla tube exceeding the the calyx except in L. Lemmoni, L. maculatus and forms of L. densiflorus; herbage ciliate-pubescent.

a. Flowers in small heads; corolla two and one-half lines long, leaves entire. 19. *L. maculatus*.

b. Flowers in numerous small heads; corolla twice the calyx or less, pale yellow with darker throat. 20. *L. Lemmoni*.

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c. Flowers in heads; corolla funnelform, with purple to white limb, equalling or exceeding the tube. 21. *L. densiflorus.*

d. Flowers in large heads with broad bracts; corolla tube averaging one inch, throat funnelform, brown or yellow, lobes broad, purple. 22. *L. androsaceus.*

e. Flowers white, tube little exceeding the calyx. 23. *Mariposianus.*

f. Flowers in rather small heads; corolla tube extremely narrow and long-exserted, throat short. 24. *L. parviflorus.*

g. Flowers few in an almost ebracteate cluster; plant gray with close pubescence. 25. *L. Gracioseus.*

h. Flower heads small; foliage not at all ciliate but closely spinose-toothed. 26. *L. serrulatus.*

i. Flower with golden-yellow corolla, lobes only one and one-half lines long; leaf segments linear-acerose; plant not exceeding four inches. 27. *L. acicularis.*

j. Corolla tube comparatively broad, lobes barely exceeding one line, limb yellow and reddish-purple; plant one to three inches high. 28. *L. bicolor.*

k. Corolla little exceeding the bracts, or much exserted, lobes one line long or less; bracts long-ciliate-margined. 29. *L. ciliatus.*

l. Corolla large, tube much exserted, lobes obovate or truncate, three to four lines long. 30. *L. montanus.*

m. "Corolla well exserted, lobes rose-red with semilunar vermilion spots near the base" (Greene). 31. *L. neglectus.*

1. **Linanthus dichotomus** Benth. *Gilia dichotoma* Benth.

Slender large-flowered annual, four to twelve inches high, simple or dichotomously branched, branches at first diverging from the main stem, then becoming erect, the whole plant glabrous except a slight scabrous pubescence on the upper leaves and segments of the calyx, and glandular white pubescence on the inner side of the calyx segments at the sinuses; leaves from one-half to two inches long, averaging one inch, sometimes entire and filiform, usually palmately three-parted, divisions filiform and setaceous-tipped; flowers solitary in the axils or terminal; calyx about one-half inch long with the tube slender and straight or sometimes expanded near the base, thus urn-shaped, scarious except the five ribs, prolonged into linear setaceous segments, more or less recurved; corolla white or purple, with cylindrical tube, slightly exserted in age, abruptly expanding into the short throat, limb about an inch broad, lobes ovate or roughly triangular with a slightly wavy margin; stamens nearly equalling the tube, inserted about one-third from the base of the tube, with pubescent

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LINANTHUS DICHOTOMUS.

1. ENTIRE PLANT. 2. FLOWER. 3. BASE OF OPENED COROLLA.

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appendages at the point of insertion; anthers very long and slender, more than one-half the length of the filaments; pistil reaching only one-half way up the tube in the flowering stage, stigma longer than the style; capsule equalling or slightly longer than the calyx tube, long-oval, seeds seven in each cell, small and dark, about one-half line long, covered with a loose white sheath, the whole about one line long.

From San Diego Co. northward at least as far as Napa Co. in the Coast Ranges and eastward into Arizona. Also Marysville Buttes, Sutter Co., W. L. Jepson. (Plate 6.)

2. **Linanthus Bigelovii** Greene. *Gilia Bigelovii* Gray.

Annual, three to eight inches high, dichotomously branched or simple, glabrous; leaves entire, narrow-linear, one-half to one and one-half inches long; flowers solitary, sessile or subsessile, axillary and terminal, four to six lines long, tube three lines long, almost cylindrical, scarious except the five green ribs which are recurved beyond the tube; corolla little if at all exceeding the calyx teeth.

Colorado Desert, San Diego Co., W. J. Wright. Tucson, Arizona, J. W. Toumey.

3. **Linanthus Jonesii** Greene. *Gilia Jonesii* Gray.

Annual, four to six inches high, very slender, slightly branched, leaves and branches almost capillary, fine glandular pubescence on the inflorescence; flowers sessile; calyx three and one-half lines long, lobes not exceeding one line; corolla one and one-half times the calyx.

Lagoon Head, Lower California, Edward Palmer, and probably within the California border.

4. **Linanthus dianthiflorus** Greene. *Fenzlia dianthiflora* Benth. *Gilia dianthiflora* Steud. *G. dianthoides* Endl.

Annual, three to six inches high, usually diffusely branching from the base; stems and herbage slightly white-woolly; leaves one inch long or less, narrowly linear; inflorescence axillary and terminal, single, on pedicels from one-eighth to two inches long; calyx three to eight lines long, lobes merely prolongations

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of the narrow ribs, longer than the scarious tube, even thrice its length; corolla broad-funnelform, tube two lines long, dark brown, throat ample, yellow, lobes four to six lines long, broad-obovate, margins fringed, purple, pink or white; stamens inserted at the top of the tube, equalling the throat, anthers small, oblong; capsule three lines long, exceeding the tube of the calyx, bursting it, ovules many, seed-coat pitted.

Common on the western side of the state from San Diego Co. to Santa Barbara Co.

5. **Linanthus liniflorus** Greene. *Gilia liniflora* Benth. *G. pharnaceoides* Benth. *L. pharnaceoides* Greene. *G. liniflorus var. pharnaceoides* Gray.

Slender annual, from three inches to two feet high, usually about one foot, branches dichotomous or alternate, forming a wide angle with the stem, stem and branches filiform, glabrous, or with very few scattered hairs; pubescence of herbage short and scabrous, rarely glandular on the calyx; leaves opposite below, alternate above, lower five to six-parted, divisions about three-fourths inch long, slender and with revolute margins and cuspidate tips, divisions fewer and shorter upwards on the branches, those of branchlets simple and minute; flowers about one-half inch long and as broad as long, scattered, on capillary pedicels varying from a line or two to one and one-fourth inches in length; calyx about two lines long, rarely longer, campanulate, segments about equalling the tube, narrow-lanceolate and cuspidate-tipped; corolla white or purplish, tube about one line long, cylindrical, throat one line long, broadening rapidly, lobes broad-obovate, three to four lines long; stamens inserted below the sinuses, reaching about half way up the lobes, a pilose ring at the base of the filaments; anthers round, sometimes declined; style and stigma slightly exceeding the stamens; stigma one-half line long, three-parted; capsule about one and one-half lines long, tapering at the base; seeds oblong, six in each cell.

Foothills and plains along the coast from San Diego to San Mateo and Santa Clara Cos. Specimens from the central counties much less delicate than southern forms. (Plate 7.)

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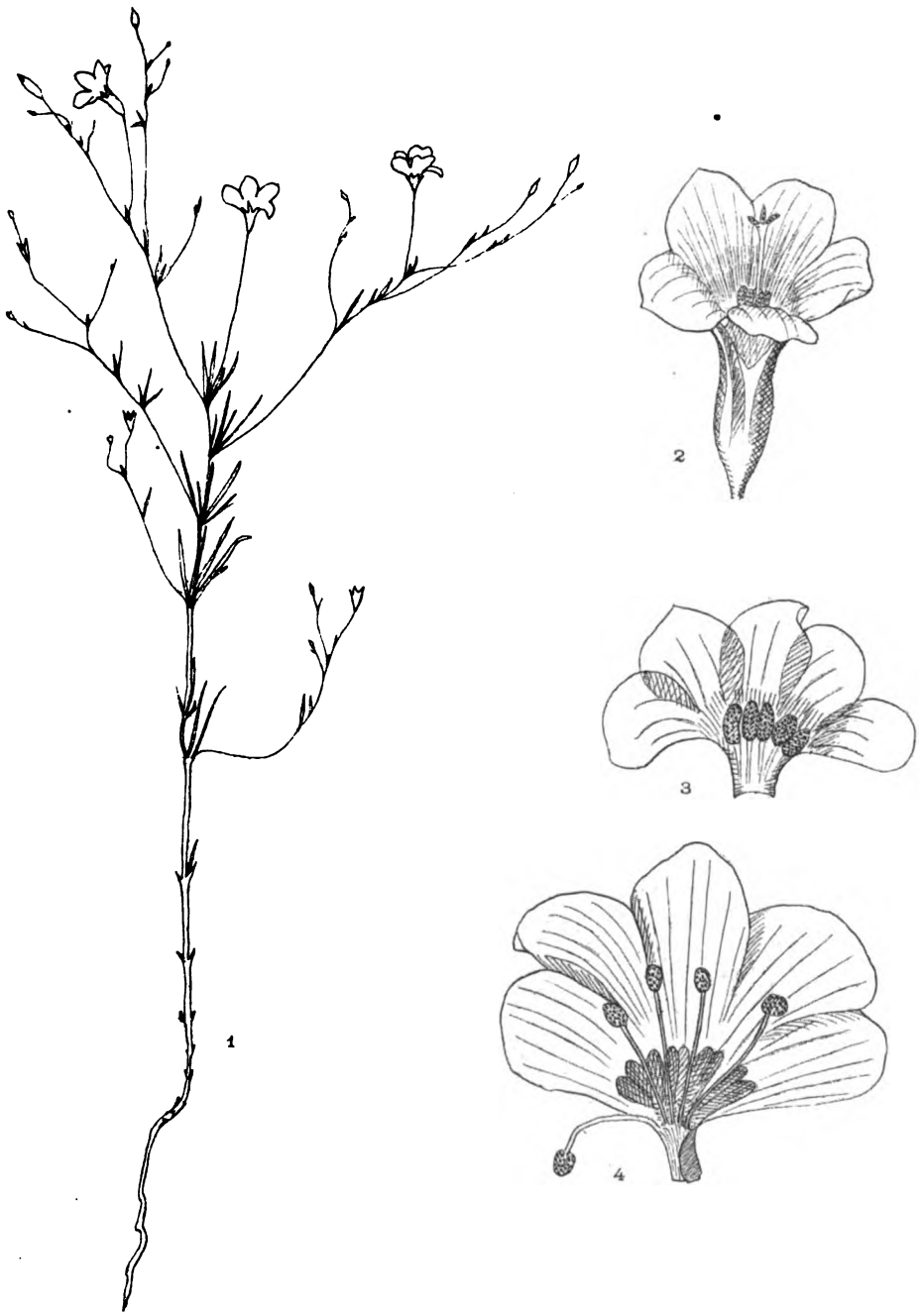

PHOTO-LITH BRITTON & REY S.F.

LINANTHUS LINIFLORUS.

1 ENTIRE PLANT. 2. FLOWER. 3. COROLLA OF YOUNG FLOWER OPENED.
4. COROLLA OF OLD FLOWER OPENED.

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6. **Linanthus filipes** Greene. *Gilia filipes* Benth.

Very slender annual, occasionally simple but usually more or less diffusely and dichotomously branched, branches filiform, diverging, often making the plant broader than high; sparse soft white pubescence on the stem and branches, longer and thicker at the base of the branches, numerous short ascending bristles on the leaves and calyces make those organs very scabrous, especially the leaves; leaves about one-fourth inch long, entire or three- to five-parted, divisions filiform, cuspidate-tipped; flowers small, about one-fourth inch long, numerous, on slender capillary pedicels from one-half to one inch long, terminal and axillary; calyx usually about one line long, extremes one-half line and two lines, campanulate, five segments white-setaceous-tipped, various in length compared with the tube, the latter slightly scarious between the ribs; corolla white and of delicate texture, tube about equalling the calyx tube, narrow-cylindrical, limb about two lines long, campanulate, segments obovate, margins entire or the ends slightly crenate; stamens regularly inserted at the top of the tube, filaments slender, about two-thirds the length of the limb; capsule exceeding the calyx tube, seeds one or two in each cell.

Common on open slopes of the foothills of the Sierra Nevada Mts. and the Coast Ranges, from Shasta Co. south in the Coast Range to Humboldt Co., and south in the Sierra Nevada Mts. to Fresno Co.

7. **Linanthus pusillus** Greene. *Gilia pusilla* Benth.

Slender branching annual, two to six inches high, branches very slightly divergent to rarely decumbent, stems and branches filiform; pubescence slight on stem and branches, not scabrous, but scabrous on leaves, and absent or sparse and scabrous on the calyx; leaves one-fourth inch long or less, cuspidate-tipped, upper sometimes entire, lower three- to five-parted; flowers very small and numerous on capillary pedicels not exceeding one inch or subsessile; calyx subcylindrical about one and one-half lines long, segments about one-half the tube, erect, setaceous-tipped; corolla about one and one-half lines long, white, or purple, equalling the calyx or slightly exserted, more exserted in age by

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the growing capsule, tube shorter than the limb, expanded at the base around the capsule, upper part narrow-cylindrical, lobes narrow-obovate, convolute; stamens inserted near the sinuses, about two-thirds the length of the lobes, sometimes declined; style longer than the filament, stigma short; capsule narrow-cylindrical, about equalling or slightly exceeding the calyx tube, seeds minute, "three to five" (Gray).

San Jacinto, Riverside Co. Witch Creek, San Diego Co. Hullville, Lake Co. St. Helena, Napa Co. Howell Mountain, Napa Co.

Var. **Californicus.** *Gilia pusilla Californica* Gray. Plant larger than the species, sometimes diffusely branching; corolla often twice the calyx.

San Luis Obispo Co., Mrs. R. W. Summers. Elk Grove, Sacramento Co., W. C. Blasdale.

8. **Linanthus Harknessii** Greene. *Gilia Harknessii* Curran.

Slender annual, from two to ten inches high, averaging six inches; pubescence very slight or lacking on the stems; leaves small at the base, often becoming larger, one-half to three-fourths inch, on the middle of the stem, and first nodes of the branches, three- to five-parted, becoming much smaller and simpler at the ends of the branches, edges revolute, tips mucronate; flowers one or two lines long, on pedicels varying from one-fourth to one and one-fourth inches long; calyx about one line long, campanulate; corolla white, minute, little exserted beyond the calyx, lobes broadly acute; stamens about three-fourths the length of the flower; capsule equalling the calyx tube, oval, seeds one in each cell.

Middle and high Sierra Nevada Mountain regions, from Modoc Co. south to Mariposa Co.

9. **Linanthus Bolanderi** Greene. *Gilia Bolanderi* Gray.

Slender annual, stems and branches filiform, usually branching dichotomously, about one span high; minute pubescence on the stem and branches, scabrous on the leaves, none on the calyx, or sometimes glandular on the calyx and pedicels and on

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the stems just below the nodes; leaves about one-fourth inch long, segments three to five, cuspidate-tipped; flower pedicels from one-fourth to one and one-fourth inches long; calyx about one-fourth inch long, narrow-cylindrical; corolla all white or with purple-tipped lobes, sometimes with dark reddish-purple spots at the base of the lobes, tube about equalling the calyx, or slightly exceeding it, limb always exserted, salverform in full bloom, lobes broad-obovate with entire edges; stamens inserted just below the sinuses, slightly exserted beyond the throat, anthers round; style long but stigma not exserted beyond the throat; capsule not quite equalling the calyx, teeth broader at the apex than at the base, seeds two to five.

Shasta Co. Humboldt Co. Type from Ukiah, Mendocino Co. Lake Co. Mt. Hamilton, Santa Clara Co., A. Kellogg. Lassen Co. Cloverdale, Mr. Sherlocks. Mariposa Co., J. W. Congdon.

10. **Linanthus ambiguus** Greene. *Gilia ambigua* Rattan.

Annual, four to six inches high, branching with filiform stems, these smooth to the touch, and glabrous to the naked eye, but very minutely and sparsely puberulent; leaves and calyx lobes scabrous-pubescent; leaves five- to seven-parted, two to three and one-half lines long; inflorescence one-to three-flowered from the axils of the upper leaves, flowers on capillary pedicels from one to eight lines long; calyx two and one-half to three lines long, narrow-cylindrical, hyaline spaces very narrow, lobes one line or less long, aristate-subulate; corolla one-half to three-fourths inch long, funnelform, tube one and one-half to two times the calyx, dark purple, throat two lines long, purple below, yellow above, lobes two and one-half lines long, blue-purple, broad-ovate; stamens and style exserted, but only one-half as long as the lobes, anthers oval, yellow; capsule narrow-oblong, included in the tube of the calyx, many seeded.

San Carlos Mt., San Benito Co., Alice Eastwood. Hernandez, San Benito Co. Loma Prieta, Santa Cruz Co., J. B. Davy. On Oak Hill, near San José, Santa Clara Co. Mt. Hamilton, Santa Clara Co., Alice Crane. Livermore, Alameda Co., W. L. Jepson.

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11. **Linanthus Rattani** Greene. *Gilia Rattani* Gray.

Slender annual, two to ten inches high, branching, sometimes dichotomously; leaves from one-eighth to one-half inch long, three- to five-parted, sometimes with a few small glands as well as scabrous pubescence; calyx about two and one-half or three lines long, narrow, nearly cylindrical, lobes only one-half the length of the tube, acute; corolla one-half inch long, white, or the tube pale at the base shading to red-purple at the top, tube much exserted, about equalling the throat and lobes, slender, cylindrical, throat short, purple and cream, lobes slender-oblong, light lavender; stamens inserted just below the sinuses, filaments extremely slender, anthers comparatively large, oval, sometimes declined.

Mariposa Co. Lake Co. Forest Grove, Santa Clara Co., W. L. Jepson.

12. **Linanthus Parryae** Greene. *Gilia Parryae* Gray.

Annual dwarf plant, one to four inches high, more or less matted; stems and foliage soft-pubescent; leaves crowded at the base, from one-fourth to one-half inch long, five- to seven-parted, sometimes alternate upward; inflorescence somewhat congested, subsessile or short-pediceled; calyx campanulate, tube short, lobes with hyaline portions bordering the ribs, long and spreading, spinulose, constricted over the growing capsule; corolla one-half to three-fourths inch long, purple, yellowish or white, with very short tube, ample expanding throat with five broad scale-like appendages dark in color surrounding the summit, opposite the obovate, spreading lobes, showing through on the outside; stamens inserted at the top of the tube, filaments broad at the base and dark, about equalling the throat, anthers oblong; capsule oblong, seeds small and numerous.

From Kern Co. south. Manzana, Los Angeles Co., J. B. Davy. Mescal Creek, San Antonio Mts., Los Angeles Co., H. M. Hall.

13. **Linanthus demissus** Greene. *Gilia demissa* Gray.

Annual, an inch or so high, without branches except those forming the inflorescence, soft-pubescent, especially the stems;

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leaves less than one-fourth inch long, three- to five-parted, equalling the internodes; inflorescence a terminal cluster nearly as broad as the plant is high; calyx campanulate, the hyaline tube split when in full flower, lobes linear, straight or slightly recurved; corolla five to six lines long, with proper tube one line long, ample throat two and one-half to three lines long, lobes naked and obovate, obtuse; stamens with triangular dilated bases, inserted at the top of the tube, included in the throat, anthers oblong-linear; pistil equalling the throat, stigma segments thread-like.

"Southeastern California" (Greene). None seen except from Arizona.

14. **Linanthus Pacificus.**

Annual, three to eight inches high, diffusely branching, branches alternate or opposite, stems and herbage puberulent, not at all scabrous; leaves three- to five-parted, four to six lines long, setaceous-tipped; flowers single or somewhat clustered; calyx four or five lines long, tube mainly hyaline, two and one-half to three lines long, cylindrical, lobes little spreading if at all; corolla tube six to seven lines long, exceeding the calyx by one line at least, purplish-red, limb open-funnelform, throat about two and one-half lines long, the pinkish lobes three lines, dark-red blotches at the base of the lobes on the throat; stamens inserted at the top of the tube about equalling the throat, anthers oblong; stigmas about equalling the filaments.

Type from Cootea, Palomar, Riverside Co., W. L. Jepson and H. M. Hall.

15. **Linanthus concinnus.** *Gilia modesta* Hall.

Annual, four to six inches high, branching more or less dichotomously, branches making a broad angle with the main stem, stems slightly puberulent, leaves more so, lower pair or two of leaves entire, the rest three- or four-parted nearly to the base, becoming five lines long, divisions slender; flowers single or three to four congested, axillary or terminal, very short pediceled; calyx four to five lines long, tube four lines, mainly hyaline, urn-shaped, pungent-tipped; corolla with tube about

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one-half line long, throat one to two and one-half lines, funnelform, lobes three lines long, obovate, tube white, throat yellow, lobes white with two dark lines at the base of each; stamens inserted at the top of the tube, one exceeding the rest but the longest only one-half the throat, anthers oblong.

Type from San Antonio Mts., Southern California, 6000 feet altitude, H. M. Hall. Elysian Park, Los Angeles Co., Mr. and Mrs. Grout.

16. **Linanthus aureus** Greene. *Gilia aurea* Nutt.

Annual, three to six inches high, diffusely branching, stems filiform, nearly glabrous, foliage scabrous-pubescent; leaves three- to five-parted, divisions about two lines long, rather thick, cuspidate; flowers from one to several from a leaf axil, on pedicels varying from one line to one inch; flowers four to six lines long; calyx three to four lines, herbaceous ribs broad, hyaline portion between narrow, tube narrow-funnelform, lobes somewhat spreading; corolla with tube one line or less long, constricted at the top, throat funnelform, two lines long, a dark reddish band on the lower half of the throat and the upper part of the tube, lobes two to two and one-half lines long, obovate, bright golden-yellow; filaments inserted just below the sinuses, hardly one-half line long, anthers oblong; style filamentous, stigmas equalling the corolla lobes.

Darwin Mesa, Inyo Co. Mojave Desert, San Bernardino Co., and Arizona. Type locality "Santa Barbara" (Acc. to Bot. Death Valley).

17. **Linanthus Nuttallii** Greene in herb. *Gilia Nuttallii* Gray.

Woody-stemmed perennial, about one span high, profusely branching from the base; foliage and stems puberulent to nearly glabrous; leaves three- to five-parted to the base, lower entire, these and the segments spatulate, lax, acute, curving upward if at all; inflorescence in axillary and terminal clusters; flowers short-pediceled or subsessile; calyx four and one-half lines long, cylindrical, mostly herbaceous, lobes about equalling the tube; narrow-lanceolate; corolla about nine lines long, tube equalling or slightly exceeding the calyx, externally pubescent, throat one

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to one and one-half lines long, open, bright yellow, lobes three lines long, narrow-truncate, pale yellow; stamens inserted in the middle of the throat, included, anthers oval, stigmas included; capsule oblong, tapering at the base, seeds two in each cell (?).

Santa Rosa Indian Reservation, El Toro Mt., H. M. Hall. Mountains in San Bernardino Co., S. B. Parish. Kaweah River Basin, R. Hopping. Lake Tahoe, W. C. Blasdale. Eastern Oregon, W. C. Cusick, 7–8000 feet. Cascade Mts., Washington, 5–6000 feet, O. D. Allen.

18. **Linanthus floribundus** Greene in herb. *Gilia floribunda* Gray.

Woody perennial, simple or much branched from the base, very slightly puberulent or glabrous; leaves entire or three-parted, divisions narrow-linear, one-half to three-fourths inch long, recurved or straight, cuspidate, edges revolute; inflorescence of loose clusters or scattered, pedicels slender, sometimes exceeding the flower, others shorter; calyx three lines long, cylindrical, mainly herbaceous, lobes equalling the tube, cuspidate; corolla five lines long, tube one and one-half lines, included, externally pubescent, throat one line long, deep yellow with dark brown at the base, lobes two to three lines long, obovate nearly white; stamens inserted in the middle of the throat, included.

Near the southern border of the state. Coulter, E. W. Morse. Cleveland, Arizona, E. Palmer. San Jacinto, Mrs. Gregory. Elsinore, Riverside Co., A. J. McClatchie. Coyote Cañon, Riverside Co., H. M. Hall.

19. **Linanthus maculatus.** *Gilia maculata* Parish.

Annual, twelve to fifteen lines high, branching quite profusely, somewhat dichotomously, stems and herbage white-pubescent; leaves entire, the upper sometimes alternate, oblong, two and one-half lines long, thickish, spinescent-tipped; flowers mostly crowded into small head-like clusters; calyx two lines long, the green lobes with hyaline margins nearly to the apex, ciliate; corolla white, tube included in the calyx, limb rotate, two lines broad; stamens slightly exserted.

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Borders of the Colorado Desert, at Agua Caliente, San Diego Co., W. G. Wright.

20. **Linanthus Lemmoni** Greene. *Gilia Lemmoni* Gray.

Small annual, from three to six inches high, simple or diffusely branching from the base, upper branches comparatively few in most cases; pubescence soft on the stems, more or less scabrous on the foliage; leaves one-fourth inch or less long, three- to five-parted, divisions linear but not filiform, acute at the tip; inflorescence a single flower or of small heads, both axillary and terminal, on slender pedicels when solitary, subsessile in the head; calyx from one and one-half to three lines long, slenderly cylindrical or somewhat spreading at the top, lobes five, as long as the tube, acute at the tip; corolla three lines long, in large forms nearly five lines, tube bulging at the base, narrowing to expand gradually into the throat, lower part white, upper dark red, throat yellowish, lobes obovate, whitish; stamens inserted just below the sinuses, recurved in age, anthers round; seeds many.

Southern California in San Bernardino, Riverside and San Diego counties. (Plate 8.)

21. **Linanthus densiflorus.** *Leptosiphon densiflorus* Benth. *Linanthus grandiflorus* Greene.

Annual, six inches to two feet high, stout, simple or with one to two short branches near the top, stems glabrous or nearly so, herbage scabrous-pubescent and somewhat ciliate, bracts sometimes densely so at the base; leaves seven-parted, one inch long in larger forms, many of the lower, perhaps half of them drop the segments while the plant is flowering; flowers crowded in a large bracted terminal cluster, showy, subsessile; calyx nearly cylindrical five and one-fourth lines long in large forms, tube four lines long, lobes narrow-lanceolate, acute; corolla one inch long or more, tube not equalling the calyx tube, throat long-narrow-funnelform, yellow, lobes purple, pink or white; stamens inserted a little below the sinuses and little exceeding them, anthers oval.

Mendocino Co., J. B. Davy. Alameda Co., A. Kellogg. Monterey Co., Brewer. San Luis Obispo Co., Blochman. Pos-

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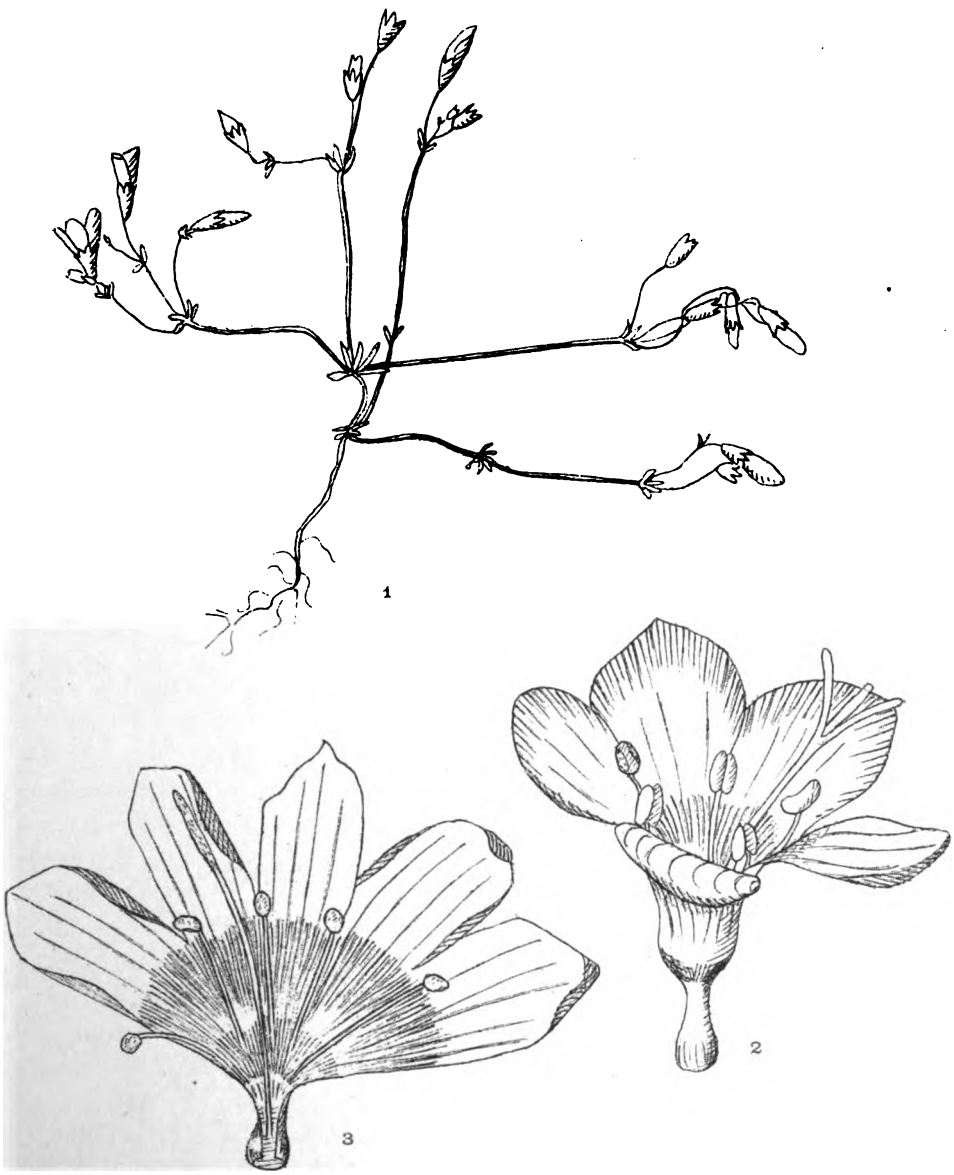

PHOTO LITH BRITTON & REY S F

LINANTHUS LEMMONI.

1. ENTIRE PLANT. 2. COROLLA. 3. COROLLA OPENED.

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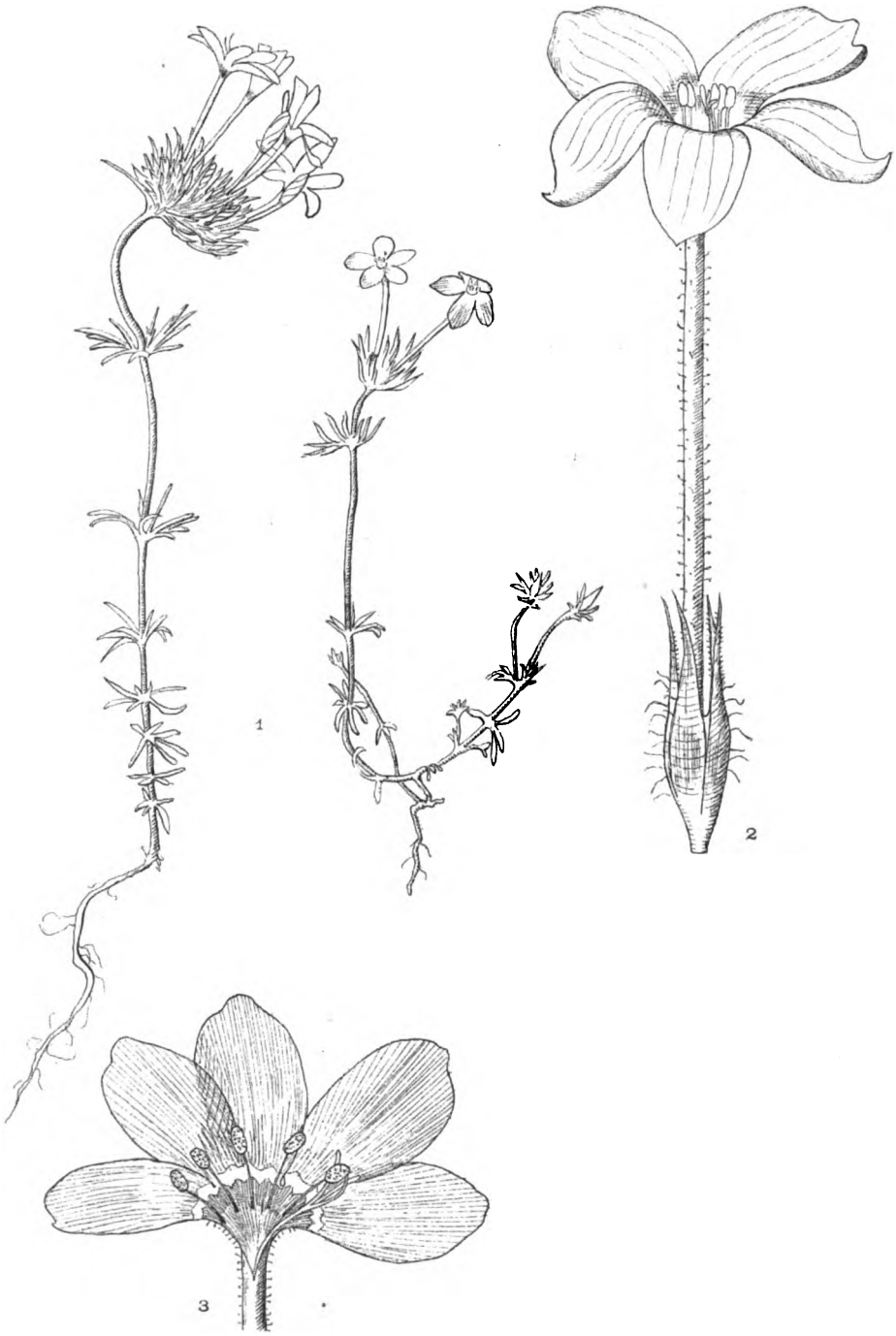

PHOTO-LITH BRITTON & REY, S.F.

LINANTHUS ANDROSACEUS.

1. ENTIRE PLANTS. 2. FLOWER. 3. UPPER PORTION OF COROLLA OPENED.

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sibly there is a variety with long exserted tube but no specimens are at hand.

22. **Linanthus androsaceus** Greene. *Leptosiphon androsaceus* Benth. *Gilia androsaceus* Gray.

Rather stout annual, from four inches to one and one-half feet high, usually simple or with few branches, sometimes several from the base, branches widely divergent; minute white pubescence on the stem and corolla tube, and a longer bristly pubescence on the foliage; leaves three- to seven-parted, not always divided clear to the base, the very lowest sometimes entire, segments spatulate except those of the upper leaves which are linear, edges revolute, tips cuspidate; inflorescence of terminal heads, showy; calyx three to four lines long, less than half as broad, five segments equalling the tube, truly herbaceous, the rest more or less scarious; corolla large, tube averaging one inch, narrow-cylindrical, funnelform throat dark brown or yellow, sometimes both, lobes broad-rounded at the apex, from dark purple to nearly white; stamens inserted at the sinuses, anthers oblong, filaments only slightly exceeding the throat; stigma with three slender divisions reaching half way up the lobes of the corolla.

Common on open hillsides. Mendocino Co., W. L. Jepson. Humboldt Co., C. C. Marshall. San Mateo Co., J. B. Davy. Sheep Creek, San Gabriel Mts., H. M. Hall. (Plate 9.)

Var. **breviculus.** *Gilia brevicula* Gray, *Linanthus breviculus* Greene. Smaller than the species, a span or less high, leaves small, narrow, hirsute; heads small, bracts few; corolla tube purple, about twice the length of the bracts, throat with dark markings at the base and yellow above, the same form to the corolla as in the species but the tube longer.

Mohave Desert, S. B. Parish. San Antonio Mountains, Southern California, H. M. Hall. San Bernardino Mts.

23. **Linanthus Mariposianus.**

Slender and sparsely branched annual, a span to one foot high, stems puberulent, leaves and bracts few, hirsute, the three to seven divisions very slender; calyx three lines long, the slender acerose lobes exceeding the tube; corolla one inch long or

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less, funnelform, the proper tube white or pale yellow, very slightly exceeding the calyx, limb as long as the tube, throat short, deep purple at the base, yellow above, lobes white or cream, long-oval to oblong; stamens inserted at the top of the dark band in the throat, reaching to the base of the lobes; three capillary divisions of the stigma only exceeding the anthers in maturity.

Type below Mariposa, Mariposa Co., J. W. Congdon, May 10, 1899. Kaweah River Basin, Tulare Co., Ralph Hopping.

24. **Linanthus parviflorus** Greene. *Leptosiphon parviflorus* Benth. *Gilia micrantha* Steud.

Rather slender annual, simple or diffusely branching, principally from the base, usually about a span high or less, occasionally one foot; pubescence short and white on the branches, sometimes almost lacking, longer and hispid on the foliage, slight on the corolla tube; leaves from one-fourth to one-half inch long, three- to five-parted, segments narrow-linear or slightly spatulate; inflorescence of numerous small terminal heads; calyx three or four lines long, narrow, teeth longer than the tube, erect; corolla with a long, very slender tube one to one- and one-fourth inches long, ending abruptly in an expanded yellow throat, lobes narrowly oval, white, cream or yellow, with dark markings outside, limb two to three lines long; stamens inserted in the throat, filaments about one-half the length of the limb, anthers oblong, large for the size of the flower; style usually exceeding the anthers, three long stigma-divisions entirely exserted or divergent, recurved in age, a conspicuous character of the type; capsule equalling the tube of the calyx, narrow at the base, seeds long and narrow.

Common in exposed parts of low hills. Shasta Co., south along the Coast Range hills to San Diego Co.

Var. **luteolus.** *Gilia micrantha* var. *aurea* Benth. *Linanthus luteolus* Greene. Leaf segments linear but not acerose; corolla lobes bright yellow, throat orange, upper tube yellow, lower reddish brown; stigmas less divergent and less exserted than in the species. Often as large flowered as var. rosaceus.

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PROM: LITH. BRITTON & REGER

LINANTHUS PARVIFLORUS VAR. ROSACEUS.

1. ENTIRE PLANT. 2. FLOWER. 3. COROLLA OPENED.

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Warner's Ranch, San Diego Co., H. M. Hall. Palomar, Riverside Co., H. M. Hall. Pacific Grove, Monterey Co., H. P. Chandler.

Var. **rosaceus** Jepson. *Linanthus rosaceus* Greene. *Leptosiphon parviflorus* var. *rosaceus* Hook. Larger than the type of the species, branching from the base; corolla an inch long or more, rose color or white, with yellow throat, tube pubescent but not glandular.

In the region of San Francisco and southward to Monterey Co. (Plate 10.)

Var. **croceus.** Annual, six to eight inches high, much branched, branches ascending, often crooked and confused; branches pubescent with soft white hairs, the base of the inflorescence woolly, revolute margins of the leaves scabrous, with short ciliate pubescence; leaves three- to seven-parted, two to four lines long, lobes spatulate to linear, acute, with very short cuspidate tips, internodes sometimes shorter than the leaves, rarely two inches long, bracts about equalling the upper leaves; inflorescence of roundish heads not exceeding ten lines in diameter; calyx four lines long, tube funnelform, coriaceous, lobes herbaceous but rigid-subulate; corolla two to two and one-fourth inches long, bright yellow, tube very slender, rarely perfectly erect, throat short and very broad, expanding very abruptly from the tube, deeper yellow than the rest, or orange, lobes obovate, fully three lines long; stamens reaching half way up the lobes, anthers oblong, style equalling the filaments, stigmas long, nearly equalling the corolla lobes.

Local, limited to about ten acres near the stage road from Colma to Blenheim, San Mateo Co., Alice Eastwood, May 19, 1901. It is labeled by Miss Eastwood in the California Academy of Sciences as a var. of Gilia androsacea.

25. **Linanthus Graciosus.**

With the habit of L. parviflorus, very diffuse, a span high, the whole plant grayish with a close pubescence; inflorescence of very many few-flowered clusters or rarely solitary, bracts few; calyx three lines long, subulate, lobes nearly equalling the tube; corolla with a very slender tube an inch long, dark purple or

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red, throat very short and broad, yellow, lobes two lines long, ovate, cream colored with a dark purple spot at the base of each; stamens shorter than the lobes; pistil exserted, often much so, stigma with three long divisions.

La Graciosa, Santa Barbara Co., and also San Luis Obispo Co., Alice Eastwood, 1896. The former the type; both specimens in the California Academy of Sciences Herbarium.

26. **Linanthus serrulatus** Greene.

Annual, four to five inches high, with many diverging ascending branches, stems puberulent, internodes not much exceeding one inch, leaves and bracts with very narrow, linear, acerose segments, cuspidate-tipped, glabrous except the margins which are not at all white-ciliate, but are closely slender-spinose-toothed; inflorescence of comparatively small clusters, not a compact head as in L. ciliatus and near relatives, therefore the individual calyces are in greater evidence; calyx five lines long, tube one line, this and the lower part of the lobes coriaceous, lobes acerose, subulate, sometimes slightly recurved; corolla about one inch long, tube slender, red, limb two lines long, lobes one and one-half lines, white to lavender; stamens shorter than the lobes, anthers nearly round, stigma about equal to the stamens; capsule oblong, three lines long.

Madera, California, Mr. Buckminster, May, 1889, seen in the California Academy of Sciences Herbarium and probably the type.

27. **Linanthus acicularis** Greene.

Small annual, two to four inches high, simple or branched; short white pubescence on the stem and corolla tube, hirsute pubescence on the leaves; leaves one-fourth inch long, lower ones shorter, three-parted, segments acerose, stiff; inflorescence of small terminal heads; calyx about two and one-half lines long, narrow, acerose teeth longer than the tube; corolla light yellow throughout or with darker throat, tube very slender, about three times the limb, the whole less than one inch in length; stamens about equalling the lobes, anthers oval; style short, three stigma segments not equalling the stamens.

On sunny hills in western California, not common. Mendocino Co., H. P. Chandler. Calistoga, Napa Co., W. L. Jepson.

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Fairfax hills, Marin Co., Alice Eastwood. Same place, C. Michener. Knight's Valley, Sonoma Co., Alice Eastwood.

28. **Linanthus bicolor** Greene. *Leptosiphon bicolor* Nutt. *Gilia tenella* Benth.

Low annual, from one to six inches high, simple or with few divergent branches, stems more or less pubescent with short bent white hairs, corolla tube slightly pubescent on the outside; leaves scabrous with short hirsute pubescence on the margins, three- to five-parted or the lowest entire and spatulate, segments of the upper leaves narrow, spatulate becoming narrower above, even acerose; inflorescence of small terminal heads; calyx about four lines long, the tube only one line, teeth narrowly lanceolate; corolla from three-fourths to one and one-fourth inches long, tube four times the length of the limb, slender but not extremely so in proportion to the limb, reddish, abruptly expanding into a yellow throat, lobes ovate, rose-purple, one to one and one-half lines long; stamens and stigma about two-thirds the corolla lobes; capsule two to two and one-half lines long, tapering at the base; seeds six in each cell(?).

Humboldt Co., J. P. Tracy. Mendocino Co., W. L. Jepson. Lake Co. Placer Co. Amador Co. Yosemite Valley, Mariposa Co. Fresno Co.

29. **Linanthus ciliatus** Greene. *Gilia ciliata* Benth.

Annual, from four to fourteen inches high, usually erect and simple, but sometimes with spreading branches principally from the base; stems puberulent, herbage conspicuously margined with long, stiff, white cilia, standing nearly at right angles to the margins, short scabrous bristles also present especially at the apex of the leaves, bracts, and calyx lobes; leaves increasing in size from the base of the plant upward, not exceeding one inch, five to seven linear divisions, cuspidate-tipped; inflorescence of close, rounded, terminal heads, bracts most conspicuously ciliated, concave on the inside, clasping the head with the tips of the divisions finally recurving, this character of clasping bracts being very characteristic of of L. ciliatus and moderately so of L. montanus; calyx one-half inch long, ribs closely approximated

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in the flowering stage, hyaline spaces between, expanding with the growth of the capsule; corolla usually little exceeding, occasionally much exceeding the calyx, three-fourths to one inch long, tube slender, cylindrical, minutely puberulent; throat yellowish, short-funnelform, lower part dark purple, upper yellow, lobes one to one and one-half lines long, salverform, purple, pink or white; stamens inserted half way up on the throat, little exceeding it; stigma reaching the point of insertion of the stamens; capsule oblong, many-seeded.

Common through the Sierra Nevada Mts. and the Coast Range Mts. from Modoc and Shasta Cos. south to San Diego Co.

30. **Linanthus montanus** Greene. *Linanthus ciliatus* var. *montanus* Greene.

Rather stout annual, a foot or less high, usually simple with long internodes; stems slightly pubescent with soft white bent hairs or glabrous; leaf-segment margins scabrous with short hirsute pubescence, bracts with long conspicuous white stiff hairs at right angles to the margins of segments; leaves three- to seven-parted, segments narrowly linear, somewhat revolute, the lower one-fourth inch, the upper one-half inch long; bracts curving about the inflorescence making a rounded head which is terminal; calyx three and one-half to five lines long, quite narrow, the very slender teeth equalling the tube, which is pubescent with long hirsute hairs; corolla about one inch long, tube red, gradually expanding into a yellow throat, lobes two or two and one-half lines long, obovate or truncate, nearly white, sometimes with purple spots at the base; stamens and stigma hardly exceeding the throat.

In Sequoia groves of the Sierra Nevada Mts. Calaveras Co., J. B. Davy. Yosemite Valley, Mariposa Co., W. Brown. Lake Eleanor, Tuolumne Co. Bakersfield, Kern Co. E. M. Day. In habit like large forms of L. ciliatus but differing in the much larger corolla.

31. **Linanthus neglectus** Greene.

A span high, with few branches, stems puberulent, leaves few, hispid, three-fourths inch long; inflorescence a single flower,

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or two to three in a terminal cluster, surpassed by larger clusters on elongated peduncles; calyx and especially the bracts glandular and with some white ciliate hairs; calyx six lines long with a short tube and long acerose lobes with hyaline margins part way up, often recurved; flowers not seen.

Valleys of the Sierra Nevada Mts. in the region of Lake Tahoe and in the State of Nevada. See Greene's description, Erythea, iii. 24.

PHLOX LINN.

Woody-stemmed perennials of high altitudes, leaves opposite, entire; corollas strictly salverform.

KEY TO THE SPECIES.

A. More or less matted; leaves short and crowded.
- *a*. Very densely caespitose and lanate-canescent; leaves subulate. 1. *P. canescens*.
- *b*. Less densely caespitose and less canescent; leaves ovate to lanceolate. 2. *P. Covillei*.
- *c*. Loosely, or somewhat densely tufted, not canescent; leaves acerose; calyx sinuses not replicate. 3. *P. Douglasii*.
- *d*. Loosely tufted; calyx sinuses replicate. 4. *P. austromontana*

B. Not matted; leaves long, not crowded.
- *a*. Branches ascending; leaves broad-lanceolate to ovate. 5. *P. adsurgens*.
- *b*. Branches nearly erect; leaves narrow-lanceolate, not exceeding four lines. 6. *P. dolicantha*.
- *c*. Erect; leaves linear, one to two lines wide. 7. *P. longifolia*.
- *d*. Erect, glandular-viscid above; leaves narrow-oblong, tapering at both ends. 8. *P. occidentale*.
- *e*. Erect, canescent; leaves narrow-lanceolate to linear, margins cartilaginous. 9. *P. Stansburyi*.

1. Phlox canescens Torr. and Gray.

Perennial, growing in very densely appressed mats, lanate-canescent, foliage bluish-gray; leaves but two to three lines long, subulate, pungent; corolla white, "tube yellow" (Torrey), tube twice or thrice the length of the calyx, lanate at the base, lobes broadly obovate, style not half as long as the tube; capsule one-seeded.

Warner Mts., 8000 feet, Mrs. C. C. Bruce. Rocky flat sage-bush land, Modoc Co., M. S. Baker.

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2. **Phlox Covillei** Nelson.

Perennial, caespitose-depressed, grayish with canescent pubescence; leaves ovate to broad-lanceolate, margins cartilaginous, reflexed, central portion thickened with prominent grooves on each side; calyx glandular-pubescent, lobes thick and broad, like the leaves; corolla white, more than twice the calyx.

Black Cañon, White Mts., Mono Co., Coville and Funston. High Sierra Nevada Mts., H. M. Hall (?).

3. **Phlox Douglasii** Hook.

Loosely or densely tufted perennial, forming mats, leaves crowded on the stems, rigid, acerose, slightly pubescent or glabrous; flowers scattered on short pedicels or subsessile, usually solitary on the annual shoots; calyx without salient angles; corolla tube usually exceeding the the calyx lobes, three to four lines long, obovate, various shades of purple, lilac and white on the same plant.

Common at high altitudes throughout the Sierra Nevada Mts. Trinity Summit, Humboldt Co., W. C. Blasdale. Yosemite Valley, Mariposa Co., W. Brown. San Antonio Mts., Southern California, H. M. Hall.

4. **Phlox austromontana** Coville.

Near P. Douglasii but less matted, leaves usually less crowded and longer, salient angles to the calyx between the ribs, calyx conspicuously pubescent; two or more flowers on the annual shoots.

Head of Davis Creek, Modoc Co., Mrs. C. C. Bruce. Trinity Summit, Humblodt Co., W. L. Jepson. San Bernardino Mts., S. B. Parish. San Jacinto Mts., Riverside Co., H. M. Hall. (Plate 11.)

5. **Phlox adsurgens** Torr.

Slender perennial, with suffrutescent base lying more or less on the ground, with several ascending branches which are mainly herbaceous, glabrous, except the inflorescence which is minutely glandular; leaves opposite, an inch long or less, broad-lanceolate to ovate, not fascicled, shorter than the internodes; flowers

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PHLOX AUSTROMONTANA.

1. PORTION OF PLANT. 2. FLOWER. 3 COROLLA OPENED.

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scattered or corymbose; calyx three and one-half to four lines long, slender, mostly hyaline, this portion slightly replicate, lobes linear and very slender, becoming recurved; corolla tube nearly twice the calyx, very slightly pubescent, lobes obovate three and one-half lines long; one or two stamens slightly exceeding the tube; style included, one-half or more than one-half the corolla tube, ovules solitary in each cell.

Deadwood, Trinity Co., W. C. Blasdale. Seiad Valley, Siskiyou Co., Mrs. Stringer. Humboldt Co., H. P. Chandler. Coniferous forest, Mud Spring to Trinity Summit, Humboldt Co., W. L. Jepson. Mariposa Co., W. C. Blasdale.

6. **Phlox dolicantha** Torr. and Gray.

Perennial, about one span high, puberulent, becoming glabrous at the base; leaves about one inch long, not exceeding four lines in width, lanceolate, not crowded, but surpassing the internodes; flowers scattered, or in groups of three; calyx from one-half to three-fourths inch long, hyaline portion hardly if at all replicate, ribs prolonged into lax, acerose lobes equalling or exceeding the tube; corolla one and one-half to two inches long, limb an inch in breadth, white, lobes obovate and entire; stigma equalling the tube; "seeds one in each cell" (Torrey).

San Bernardino Mts., S. B. Parish, also H. M. Hall.

7. **Phlox longifolia** Nutt.

Perennial, a span or so high, erect, glabrous or "finely pubescent" (Nelson), considerably branched from the woody base; leaves one to two inches long, one to two lines wide, midrib prominent on the under side, margins slightly thickened, leaves exceeding the internodes, occasionally fascicled in the axils; flowers solitary or in a few-flowered corymb, borne on pedicels one-half to one and one-half inches in length; calyx four lines long, hyaline portion slightly replicate, lobes subulate to acerose, about one-half the tube or a little more, tube slightly constricted at the top; corolla white, tube slightly exceeding the calyx, lobes four to five lines long, tapering at the base, expanded apex cuneate, style shorter than the calyx.

Siskiyou Co., C. B. Bradley.

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Var. **puberula** E. Nelson. Densely glandular-pubescent on the pedicels; leaves and flowers smaller than in the species.

Dixey Mts., Lassen Co., M. S. Baker and F. Nutting, California Academy of Sciences.

8. **Phlox occidentale** Durand.

Perennial, a span or two high, suffrutescent at the base, glandular-pubescent and somewhat viscid above, branches ascending or erect; leaves one and one-half inches long or less, not crowded, but exceeding the internodes, narrow-oblong, tapering at both ends, some alternate above, rarely fascicled in the axils; flowers solitary or in groups of two or three; calyx four lines long, hyaline portion slightly replicate, lobes subulate, half the tube, erect; corolla tube exceeding the calyx, but hardly twice its length, lobes four lines long, obcordate, "white to rose; ovules solitary in each cell" (Nelson).

Near Kenyon, Fresno Co., H. M. Hall and H. P. Chandler. Fresno Co., Alice Eastwood, G. Eisen. Amador Co., Mrs. K. Brandegee. El Dorado Co., G. P. Rixford. Plumas Co., F. McNaught. Siskiyou Co., H. E. Brown, Miss Cummings. This is the California species, resembling closely P. speciosa of the Rocky Mountains and of the State of Washington.

9. **Phlox Stansburyi** Heller. *P. speciosa var. Stansburyi* Torr. *P. longifolia var. Stansburyi* Gray.

Perennial, about one span high, stems many, leafy, the whole plant canescent, branches glandular above; leaves narrow-lanceolate to linear, margins slightly cartilaginous, midrib prominent; inflorescence of few-flowered, bracted clusters; hyaline spaces of the calyx markedly replicate; corolla tube twice the calyx, lobes three lines long, obovate.

Willow Creek, Panamint Mts., Coville and Funston.

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LIST OF PLATES.

FACING PAGE

1. Flower and Fruit of Six Species 1
2. Polemonium parvifolium 8
3. Navarretia squarrosa 18
4. Gilia latiflora; G. achilleaefolia; G. multicaulis 36
5. Gilia Davyi 30
6. Linanthus dichotomus 46
7. Linanthus liniflorus 48
8. Linanthus Lemmoni 56
9. Linanthus androsaceus 57
10. Linanthus parviflorus var. rosaceus 59
11. Phlox austromontana 64

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INDEX.

PAGE

Aegochloa atractyloides ... 21
cotulaefolia ... 14
intertexta ... 16
pubescens ... 17
pungens ... 18
Bonplandia ... 1
Cantua ... 1
aggregata ... 37
Capitata ... 23
Cobaea ... 1
Collomia ... 9 (2, 3, 4, 5)
gilioides ... 26
grandiflora ... 10 (9)
gracilis ... 25
heterophylla ... 12 (10)
leptalea ... 29
linearis ... 10 (9)
mazama ... 11 (10)
tinctoria ... 11 (9)
Elaphocera ... 24
Eugilia ... 23 (5)
Fenzlia *dianthiflora* ... 47
Gilia ... 22 (2, 3, 4, 5)
abrotanifolia ... 35 (24)
achilleaefolia ... 36 (24, 34)
aggregata ... 37 (3, 24)
var. Bridgesii ... 38
ambigua ... 51
androsaceus ... 57
aristella ... 11
atractyloides ... 21
aurea ... 54
Bigelovii ... 47
Bolanderi ... 50
brevicula ... 57
Californica ... 41 (24)
capillaris ... 30 (23)
capitata ... 37 (24)
ciliata ... 61
Chamissonis ... 35 (24)
congesta ... 38 (24)
cotulaefolia ... 14, 17
Davyi ... 30 (23)
demissa ... 52
densifolia ... 38 (24)
var. sanctora ... 39
depressa ... 25 (23)
dianthiflora ... 47
dianthoides ... 47
dichotoma ... 46
diffusa ... 32 (23)

PAGE

Gilia *diraricata* ... 20 (26)
filicaulis ... 19
filifolia ... 39
filiformis ... 30 (3, 23)
filipes ... 49
floccosa ... 40
floribunda ... 55
gilioides ... 26 (33)
glutinosa ... 26
gracilis ... 25 (3, 23)
Hallii ... 42
Harknessii ... 50
heterodoxa ... 19
heterophylla ... 12
Hookeri ... 41
inconspicua ... 31 (23)
var. sinuata ... 32
intertexta ... 16
Jonesii ... 47
latiflora ... 27 (33)
var. exilis ... 27
latifolia ... 27 (23)
Lemmoni ... 56
leptalea ... 29 (23)
leptomeria ... 31 (23)
leucocephala ... 14
linearis ... 10
liniflora ... 48
var. pharnaceoides ... 48
lutescens ... 40 (24)
maculata ... 55
Matthewsii ... 43 (25)
mellita ... 18
micrantha ... 58
var. aurea ... 58
millefoliata ... 33 (24)
minima ... 14
modesta ... 53
multicaulis ... 34 (24)
var. alba ... 35
var. detonsa ... 35
var. eximia ... 35
Nevinii ... 33 (24)
Nuttallii ... 54
ochroleuca ... 32 (23)
pallida ... 37
Parryae ... 52
peduncularis ... 34 (24)
pharnaceoides ... 48
prostrata ... 13
pubescens ... 17

Digitized by Google

PAGE
Gilia pungens 41 (18, 25)
var. caespitosa 41
var. Hallii 42
var. Hookeri 42
var. squarrosa 41
var. tenuiloba 43
pusilla 49
var. Californica 50
Rattani 52
Schottii 43 (25, 44)
setosissima 44 (25)
var. exigua 43
sparsiflora 40 (24)
squarrosa 18
staminea 36 (24)
tenella 61
tenuiflora 28 (23)
var. Purpusii 29
var. latiflora 27
var. altissima 28
tenuiloba 43
Traskiae 26 (23)
tricolor 33 (24)
virgata 39 (24)
var. filifolia 39
var. floccosa 40
var. floribunda 40
viscidula 21
var. heterodoxa 19
Hoitzia 1
squarrosa 18
Hugelia 24 (2)
densifolia 38
lutea 40
virgata 39
Ipomopsis 24 (2)
Langloisia 25 (2)
Matthewsii 43 (3)
Schottii 43 (3)
setosissima 44 (3)
Leptodactylon 24 (2)
Californicum 41
Leptosiphon *androsaceus* 57
bicolor 61
densiflorus 56
parviflorus 58
var. rosaceus 59
Linanthus 44 (2, 3, 4, 5)
acicularis 60 (46)
ambiguus 51 (45)
androsaceus 57 (46)
var. breviculus 57
aureus 54 (45)
Bigelovii 47 (3, 45)
bicolor 61 (46)
Bolanderi 50 (45)
breviculus 57
ciliatus 61 (46)
var. montanus 62
concinnus 53 (45)
demissus 52 (45)

PAGE
Linanthus densiflorus 56 (46)
dianthiflorus 47 (45)
dichotomus 46 (45)
filipes 49 (45)
floribundus 55 (45)
Graciosus 59 (46)
grandiflorus 56
Harknessii 50 (45)
Jonesii 47 (45)
Lemmoni 56 (45)
liniflorus 48 (3, 45)
luteolus 58
maculatus 55 (45)
Mariposianus 57 (46)
montanus 62 (46)
neglectus 62 (46)
Nuttallii 54 (45)
Pacificus 53 (45)
Parryae 52 (45)
parviflorus 58 (46)
var. croceus 59
var. luteolus 58
var. rosaceus 59
pharnaceoides 48
pusillus 49 (45)
var. Californicus 50
Rattani 52 (45)
rosaceus 59
serrulatus 60 (46)
Loeselia 1
Matthewsii 43
Schottii 43
Microsteria 23
Microsteris 3
Navarretia 12 (2, 3, 4, 5)
atractyloides 21 (13)
Breweri 20 (13)
cotulaefolia 14 (12)
divaricata 20 (13)
filicaulis 19 (13)
foliacea 22 (13)
hamata 22 (13)
heterodoxa 19 (13)
intertexta 16 (12)
involucrata 13
leucocephala 14 (12)
mellita 18 (13)
minima 14 (12)
mitracarpa 19 (13)
nigellaeformis 15 (12)
prolifera 15 (12)
prostrata 13 (12)
pubescens 17 (13)
pungens 18
Schottii 43 (44)
setosissima 44
setiloba 16 (13)
squarrosa 18 (13)
subuligera 21 (13, 17)
tagetina 17 (13)
viscidula 21 (13)

Digitized by Google

PAGE

Phlox 63 (1, 3, 4, 5)
adsurgens 64 (63)
austromontana 64 (63
canescens 63
Covillei 64 (63)
dolicantha 65 (63)
Douglasii 64 (63)
gracilis 25
longifolia 65 (63)
var. puberula 66
var. Stansburyi 66
occidentale 66 (63)
speciosa var. Stansburyi 66
Stansburyi 66 (63)
Polemonia 1

PAGE

Polemoniaceae 1
Polemonium 5 (1, 2, 3, 4)
antarticum 9
carneum 6
coeruleum 6
confertum 7, 9
eximium 7 (6)
humile 5, 8, 9
var. pulchellum 5, 8
micranthum 9 (6)
moschatum 8
parvifolium 8 (5, 6)
pulchellum 8 (6)
pulcherrimum 8
viscosum 5, 8, 9

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BY

W. J. V. OSTERHOUT

CONTENTS.

PAGE

I.—A Simple Freezing Microtome 74

II.—Fixation in Vacuo 78

III.—A Simple Slide Holder 81

IV.—A Rapid Method of Mounting in Aqueous Media 83

V.—Embedding Microscopic Algæ 85

VI.—Embedding with Incomplete Dehydration 87

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Vol. 2, No. 2, pp. 73-90. June 15, 1904.

CONTRIBUTIONS TO CYTOLOGICAL TECHNIQUE

BY
W. J. V. OSTERHOUT

I. A Simple Freezing Microtome.

In the *Botanical Gazette* for April, 1896 (Vol. 21, p. 195), I described a freezing device which makes use of a current of cold brine flowing through a metal chamber attached to the microtome. This proved so satisfactory that a simple microtome, especially adapted for work with it, was designed. Inasmuch as this microtome is equally adapted to other freezing apparatus, it may be described here. As shown in figure 1 it consists of an iron stand, which may be made from a piece of heavy T-rail about eight inches long with a width of four inches at the top. At one end it is cut away so as to leave the two projecting arms between which the freezing chamber *(f)* rests. For raising and lowering the chamber a micrometer screw *(s)*, together with the attached parts, was removed from a Bausch & Lomb Table Microtome (Microtome Catalogue B, 16th Ed.; No. 3050) and fastened to the stand in the manner shown in the figure. This part of the apparatus may be obtained separately from the manufacturers.

In cutting frozen tissues the hardness of the material makes it absolutely necessary to use a knife much heavier than the ordinary microtome knife. For this purpose a carpenter's plane iron is the best thing to use. In cutting the frozen mass, however, the edge is quickly dulled and needs to be sharpened very frequently. This always takes some time and in unskilled hands is a rather unsatisfactory performance.

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To obviate this difficulty I have employed the attachment shown in figure 1 at *(a)*. It is made of brass or copper and its construction will be understood by reference to figure 2, which represents it in cross section. The knife *(k)* is firmly held in place by means of the set screw *(s)*, which passes through a collar *(c)* soldered to the top plate *(p)* which is in turn fastened to the main body of the attachment by the screws *(m, m)*. A cylindrical piece of brass *(r)* serves as a roller and turns on the screws *(w, w)* as bearings. The position of these screws in

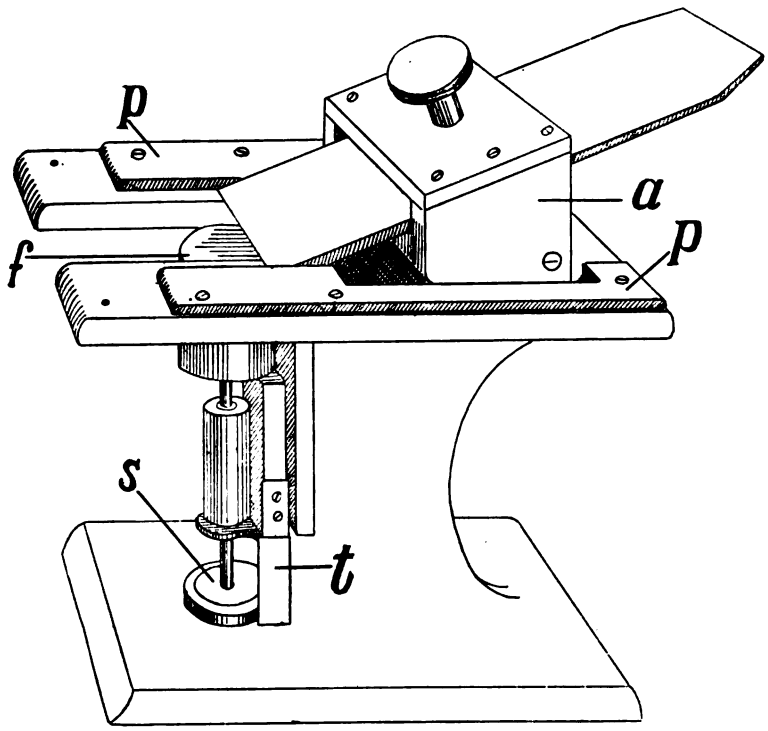

FIGURE 1.

Freezing microtome. The freezing chamber *(f)* lies between two projecting arms on which the plane iron with its attachment *(a)* travels: the plates *(p, p)* prevent it from going to far forward or back and also from slipping sidewise. The chamber is raised and lowered by means of the screw *(s)*; in contact with the milled head of the screw is a piece of metal *(t)* for the purpose of producing clicks as the screw is turned. The freezing chamber may be cooled by cold brine, carbon dioxide, ether or rhigolene.

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figure 1 serves to show the location of the roller, which does not lie directly beneath the set screw as the section indicates, but some distance behind it.

When the knife is placed for the first time on the hone, the attachment is so adjusted by means of the set screw that the ground surface lies flat or nearly flat on the hone. The flatter it lies the longer it takes to hone it, but on the other hand the iron will not require grinding so often. When the angle has been selected a mark should be made on the plane iron so that the attachment can be set at the same place again.

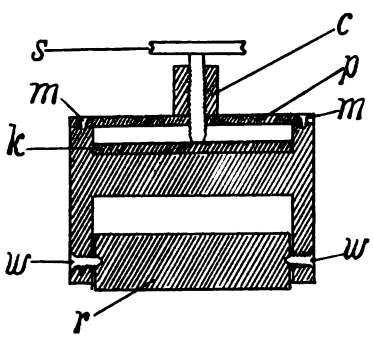

Figure 2.

A sectional view of the plane iron attachment. The knife *(k)* is firmly held by the set screw *(s)* which works in a collar *(c)* which is fastened to the plate *p:* the latter is secured by the screws *(m, m)*. The roller *(r)* is held in place by the screws *(w, w)* which serve as bearings.

As it rolls back and fourth on the hone it is kept constantly at the same angle. After grinding first on the yellow, Belgian hone with soap, and then on the water hone with water, the edge is lightly drawn across a piece of soft wood. The plane iron is then removed from the attachment and laid perfectly flat on the hone, flat side downwards, and given a few strokes. It may then be stropped in the usual way and replaced in the attachment, but this time it is placed from a half to a quarter of an inch further back so that when it stands on the microtome (as in figure 1) it is a little more nearly vertical than when it stands on the hone. The object of this is to prevent the material from coming in contact with the whole of the ground surface since it is desirable that the edge alone should touch it. A mark should be made on the plane iron so that it may at any time be reset in this position.

The plane iron with its attachment rolls back and forth on the microtome in the same manner as on the hone. Each time it goes back the micrometer screw is turned, thus raising the

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freezing chamber so that as the knife comes forward it makes a cut.

In order to prevent the edge of the knife from coming in contact with the microtome two plates (figure 1 *p*, *p*), about one-sixteenth of an inch thick and of the form shown in the figure, are fastened to the top; they not only prevent the knife edge from going back far enough to strike the top of the microtome, but also guide it in its forward and backward movement so that it does not slip to one side. It will be noticed that the cutting edge in its middle portion comes in contact with nothing but the frozen block, while at both sides it rests directly on the microtome top. This, however, is not a disadvantage since the ground surface of the plane iron makes an excellent bearing and it runs very smoothly.

In using the microtome the left hand operates the screw while the right grasps the plane iron with its attachment and shoves it back and forth, pressing it down firmly all the time. It is possible in this way to cut very rapidly. For most purposes it suffices to turn the screw continuously and steadily while with the other hand the plane iron is rapidly pushed back and forth. A small piece of tin (*t*, figure 1), bent at right angles and so fastened that its edge comes in contact with the milled head of the micrometer screw *(s)*, produces a clicking which obviates the necessity of watching the screw.

When the knife becomes dull it is only necessary to set it again in its original position in the attachment (using as a guide the mark made on the iron) and roll it back and forth a few times on the hone and then strop it as before. The whole process need not occupy more than five minutes. The usual method of sharpening the plane iron is to hold it in the hand and run it back and forth over the hone. The result is that the angle of sharpening is constantly changed and a new surface has to be ground each time, which is necessarily tedious. With the attachment here described the iron always strikes the hone at precisely the same angle and the work of sharpening becomes easy and simple.

This microtome has been found to work equally well with cold brine, carbon dioxide, ether or rhigolene. The ordinary

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apparatus for use with these substances, as sold by Bausch & Lomb, fits the attachment which is connected with the screw, as this was taken from one of their microtomes.*

The microtome has now been in use for nearly ten years. It has never been out of order or needed alteration or repairs, and it has given entire satisfaction during the whole time. Its advantages lie in its simplicity and convenience, in the fact that there is no danger of the knife springing on coming in contact with the hard block and also in the ease and certainty with which the knife can be kept in proper condition, even in unskilled hands.

* It is customary when using carbon dioxide to connect the tank with the freezing chamber by rubber tubing. This frequently becomes stopped up and bursts; flexible lead pipe (about a quarter of an inch in diameter inside) should therefore be used instead.

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II.—Fixation in Vacuo.

It is a common experience that it is more difficult to fix vegetable than animal tissues. This is usually ascribed to the presence of a cellulose wall in plants, but in reality it is largely due to the presence of air in the spaces between the cell-walls. I have found that many obstinate tissues are easily fixed if they are placed in the fixing fluid and the air then exhausted. The fluid then rushes into the intercellular spaces and fixation is more rapid than when no air is originally present.

Inasmuch, however, as fixation must usually be done in the field in order to give the best results, and as an air-pump is an inconvenient piece of apparatus to carry, it was found necessary to devise a simple form of air-pump which would answer the purpose.

Figure 3 shows the construction of the pump in detail. A piece of glass tubing twelve to fifteen inches long and a little over an inch in diameter, or, better still, a student lamp chimney (size No. 1), is carefully sealed at one end with sealing wax. For this purpose a small disc *(r)*, cut from a rubber stopper, is pushed about an inch down into the tube, or, in the case of the chimney, as far as the neck. The glass is then carefully warmed and sealing wax poured into it from a tin cup in which it is melted. In order to get as large surface of contact as possible it should be smeared upon the sides of the tube both within and without.

The piston may be prepared as follows: insert a rubber stopper at the unsealed end of the tube, press it in gently and then cut it off cleanly just at the top of the tube. In the upper half of the stopper make another cut just above the first so as to slice off a disc about an eighth of an inch in thickness. With an awl make a hole exactly in the center of this disc and force through it a brass rod (about three-sixteenths of an inch in diameter) of the form shown in the figure. This should be provided with a thread at the end and carry a nut *(n)* above the disc and a nut and washer *(w)* below it. The washer should be a little smaller than the inside diameter of the tube or chimney.

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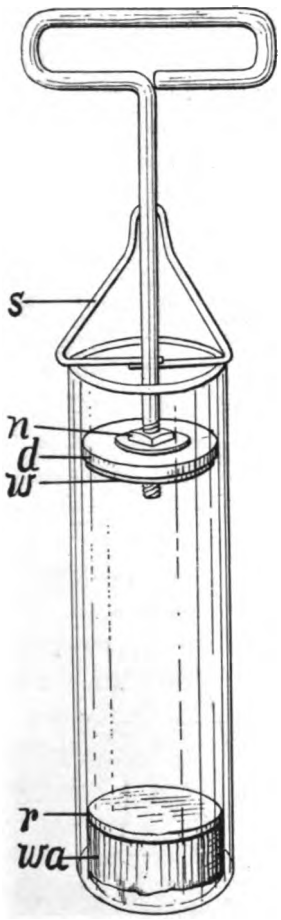

FIGURE 3.

Air pump, consisting of a glass tube sealed air-tight at the bottom with a rubber disc *(r)* and sealing wax *(wa)*, and also of a piston which consists of a brass rod furnished at the end with a nut *(n)* below which is a small washer and a rubber disc *(d)*; below this is a large washer *(w)* held in place by a nut which is not shown; the spring *(s)* keeps the piston from slipping back into the tube.

In order to use the apparatus the tissue is placed in the tube or chimney and fixing fluid is poured over it. When the piston is pushed down, the disc springs back to allow the air to escape. When it comes below the liquid it should be pulled up again. The washer prevents the rubber disc from springing downward. The result is that the column of liquid is broken in two and a very good vacuum produced, while the layer of liquid above the piston prevents the entrance of air. When the disc reaches the top of the tube the two springs *(s)* shown in the figure come into play. These are made of good steel wire about one-sixteenth of an inch thick. They act on the same principle as the spring which keeps an umbrella from collapsing, and they prevent the piston from slipping back into the tube.

The nuts should be tightly screwed up against the disc, and if air leaks along the thread it should be stopped with sealing wax. This may be readily accomplished by smearing the thread with hot sealing wax and screwing the nut down upon it. Only the upper nut need be so treated; the lower one should be left free so that it may be quickly removed if necessary. Whenever it becomes necessary to change the rubber disc in order to fit another tube, or for any other reason, it is but the work of a moment to remove the lower nut and washer and put the new disc in place.

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In order to inject tissues with fixing fluid they are placed in the tube and secured in place by means of a small wire coil, a bit of glass, or a short piece of twig wedged in place so that they cannot rise in the liquid. The fluid is then poured over them so as to cover them about an inch deep. The piston and the inner surface of the tube then receive a thin coating of vaseline to prevent the piston from sticking; this precaution is important. It should be noted also that if the disc is too thick it will not spring sufficiently and if it is too thin it will spring too easily. The piston should be forced down about half an inch below the surface of the liquid and then drawn up again, when the springs will hold it in place. Bubbles of air at once begin to pour out of the tissue and may continue to do so for half an hour or more. The piston may be occasionally lowered and raised during this time in order to hasten the process.

It may be remarked that this apparatus affords a splendid means for class demonstration of stomata, lenticels, etc., since it is only necessary to place the leaves or twigs under water and exhaust in order to see the bubbles come pouring out of the openings.

By this means tissues can be rapidly injected with fixing fluid in the field. Many flowers and other organs, which on account of their hairy or waxy coverings can not ordinarily be fixed at all, yield excellent results with this treatment.

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III.—A SIMPLE SLIDE HOLDER.

For investigations which require simultaneous treatment of large numbers of slides the ordinary slide holders used for staining purposes have frequently proved unsatisfactory. For one thing, they do not hold slides enough, and they have the further defect of carrying over quantities of one stain or liquid into another. A device which does away with both these difficulties is shown in Figure 4. It consists of a stiff coil (about

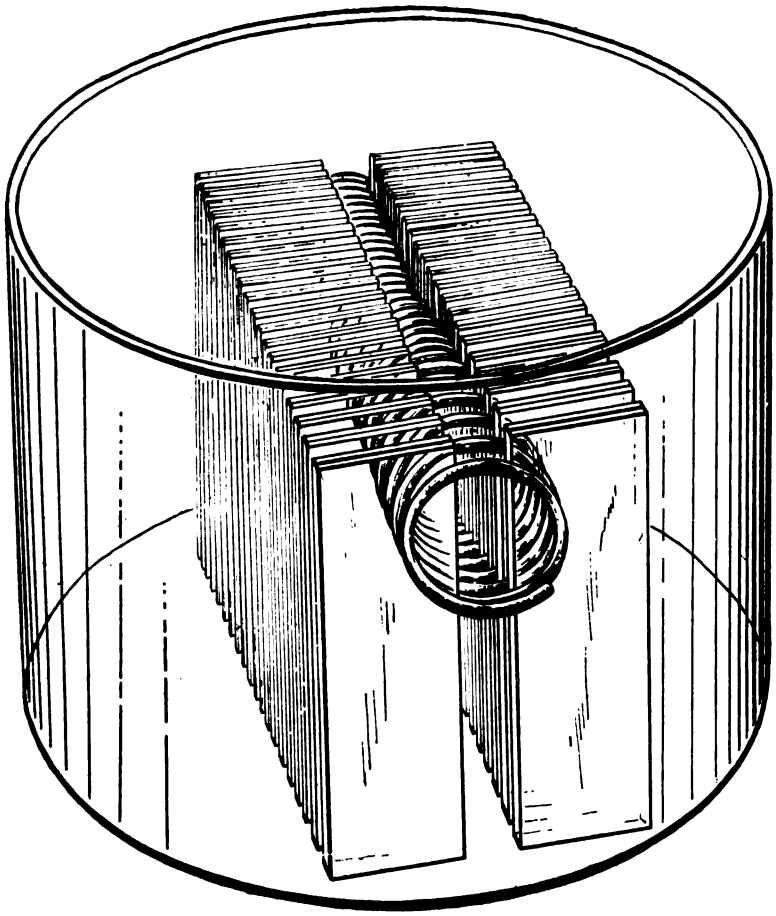

FIGURE 4.

A slide holder consisting of a coil of nickel-plated steel wire and capable of holding a number of slides in a small compass.

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an inch in diameter), of nickel- or copper-plated steel wire of good quality. In practice I have found it most convenient to use thin slides, placing two back to back and inserting in the same manner as a single slide. The coil is laid flat on the table and held down firmly with the right hand, which also holds the two slides placed back to back. These should be grasped by pressing the thumb and middle finger against the opposite ends, while the index finger presses against the edge and forces them into the coil, which in the meantime is sprung apart at the proper place with the left hand. After a few trials this can be done with ease and rapidity. When one side is full the coil may be turned over and the other side treated in the same way.

The coil should be sufficiently close and stiff to hold the slides firmly, so that the whole can be picked up and shaken without dislodging any of the slides. By varying the thickness of wire and the tightness of winding, a coil of any desired stiffness or closeness may be obtained. It should be remarked that the wire should be wound on a bar from one-fourth to one-half of the diameter desired for the coil, and should be hammered while still closely wound on the bar. A lathe is very useful for winding the coil.

By this means one hundred and twenty-five slides can be stained at once in a circular dish four or five inches in diameter, and on transferring to another dish only a few drops of liquid are carried over, provided the slides be allowed to drain for a moment on filter paper. The dishes which I have used are provided with tin screw tops like ointment pots, which effectually prevent evaporation.

Any number of slides up to one hundred and twenty-five may be used at one time in each coil. In practice it is usually advisable to fill the coil and run the slides through to a certain stage—in using the Flemming stain as far as the Safranin—and there let them remain, taking out a few at a time as needed.

To remove the slides while they are standing in the dish it is not necessary to lift the coil, since any slide may be easily slipped out sidewise and removed without disturbing any of its neighbors.

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IV.—A RAPID METHOD OF MOUNTING IN AQUEOUS MEDIA

It constantly happens in the examination of microscopic material that individual forms or stages are discovered which it is desired to preserve with as little manipulation as possible. To transfer them to glycerine jelly is often difficult or impossible while the usual methods of sealing such preparations are, to say the least, not always convenient. The following method is free from these objections and has proven very successful.

The examination is made in a drop of fluid placed on a cover glass one inch square and covered by a smaller one, usually three-fourths of an inch square; both rest on an ordinary slide. Should anything of interest be discovered the superfluous liquid is removed with a piece of blotting paper so as to leave the exposed parts of the large cover glass clean and dry. A drop of balsam dissolved in xylene is then placed on a slide and the cover glasses placed upon it in an inverted position so as to bring the smaller one underneath. The whole arrangement is shown in section in Figure 5, *(s)* being the slide, *(m)* the material, *(c)* and *(c)* the cover glasses, and *(b)* the balsam, represented by the shaded portion. The balsam should be quite fluid, so that the weight of the preparation will force it out from beneath the lower cover glass, since it will not do to press down on it for this purpose on account of the danger of forcing the water out from between the covers. Neither will it do to heat to any great extent since this may cause bubbles.

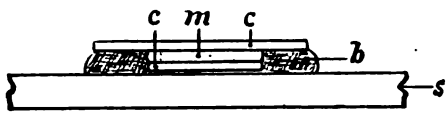

FIGURE 5.

Sectional view of mounted material showing the slide *(s)*, the covers *(c c)*, the material *(m)* and balsam *(b)*.

The preparation is now set aside to dry and treated like any balsam preparation. Larger and thicker objects, such as free hand sections, etc., may be treated somewhat differently. They may be placed on the slide in a small drop of fluid, which is then surrounded on all sides by narrow, broken fragments of cover glass. A large cover glass (about one inch square) is then placed on these supports, the superfluous liquid is removed and

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a drop of liquid balsam allowed to run in from one side to occupy the capillary space surrounding the drop.

In the course of time a cloudiness appears around the edge of the drop where it comes in contact with the balsam, but it does not spread and does not injure the preparation in any way. It might possibly be obviated by using some other solvent for the balsam.

I have now kept preparations for over two years in this way and they are entirely satisfactory, being apparently as good in all respects as when they were put up.

The advantages of the method are its quickness and convenience and the fact that the preparation is mounted just as it stands without transference or any danger of loss or disturbance.

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V.—EMBEDDING MICROSCOPIC ALGÆ.

The most serious difficulty in embedding microscopic algæ lies in the fact that they are usually mixed with dirt, which soon ruins the knife edge. This may be gotten rid of by rubbing them up gently in a considerable quantity of water and then decanting into a long tube, one-fourth to one-half an inch in diameter, closed at the lower end with a piece of rubber tubing and a burette clamp. As soon as the dirt has settled to the bottom it may be drawn off. The tube may then be shaken up and the process repeated until no more dirt remains.

After being freed from dirt the algæ must be collected into a small space in order that they may be embedded. The following method* has proved very successful for this purpose. A glass tube of about one-fourth of an inch interior diameter is first smeared at the lower end with glycerin and then dipped into a solution of collodion or photoxylin. As soon as the collodion film has become firm it is shoved down a little so as to allow the end to be cut off with the scissors. An ordinary pipette bulb is now attached to the upper end and the lower end is again dipped in the collodion solution. As soon as it is withdrawn the bulb is compressed, with the result that a collodion bubble is blown at the lower end. The bulb is kept compressed until the bubble hardens into a firm sack. The pipette bulb is now removed and the tube is filled with the water containing the algæ. These gradually sink down into the collodion sack, which may then be compressed at the top with a pair of forceps while the water is poured off. Fixing fluid may then be poured into the tube and after an appropriate time gotten rid of in the same manner. The algæ may be washed with several changes of water, in the same manner, in order to remove the fixing fluid. The sack may now be held with the forceps as just described and cut off close to the bottom of the tube. The cut surfaces may then be brushed with a solution of collodion, which serves to seal the sack. It may then be dehydrated, together with the contained algæ, and embedded in the usual way.

* See also Strasburger's Practicum, third ed., p. 366.

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It often happens that the algæ remain suspended in the water and refuse to sink to the bottom even after some days. The addition of fixing fluid to the water often causes them to sink, but even this sometimes fails. In such cases I have tried the expedient of adding a little white of egg, which soon coagulates, both in the water and in the fixing fluid, forming a flocculent precipitate which slowly settles, carrying the algæ down with it. Very obstinate cases may be treated by partly emptying the tube of water and cautiously pouring in alcohol of any desired grade. This gradually diffuses downward, and when the proportion of alcohol becomes great enough the algæ sink to the bottom.

In many cases it is possible to concentrate the algæ rapidly by simply filtering through the Schleicher & Schuell Filter paper No. 575, either with or without the use of a filter pump. This filter paper is hard and smooth, and the algæ, even when gelatinous, do not stick to it and can be washed down into a compact mass. I have also used chamois skin in the same way; in this case the filter pump is a necessity. The algæ cannot be washed down, but can be easily removed without the slightest injury (even in the case of swarm spores) by simply laying the wet chamois skin flat on a board and scraping with a knife. The knife must be pressed down firmly against the chamois skin so as to squeeze out the water (and the contained algæ) as it travels along, leaving the skin dry behind it. It will then be seen that the knife does not really come in contact with the algæ at all.

The collected algæ may be enclosed in a collodion sack as before or placed in a narrow vial and run up into paraffin by carefully decanting the successive liquids. When the paraffin is cooled the bottle is broken and the block cut in the usual way.

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VI. EMBEDDING WITH INCOMPLETE DEHYDRATION.

The complete dehydration necessary for paraffin embedding is utterly ruinous to many plant tissues and is always more or less deleterious even under the best circumstances. This is especially true of many algæ, whose gelatinous walls shrink or collapse during the process of embedding and do not regain their normal appearance even when the sections are soaked for a considerable time in water. An additional difficulty is that such tissues become exceedingly brittle in paraffin so that they do not give the best results in cutting. The process of embedding such tissues in paraffin is usually tedious, requiring nine or ten days and necessitating frequent changes of the material.

Sometime ago I began experimenting with the process of embedding in soap with a view to obviating these difficulties. My first attempts in this direction were with the well-known formulæ given in "Lee's Vade Mecum" (4th ed., p. 95 ff). While the sections showed an improvement over those obtained from paraffin they were still far from satisfactory, especially for delicate algæ. The dehydration goes too far to give the best results. I therefore endeavored to find a soap which could be used in watery solution for embedding purposes. After extensive experiments it became apparent that cocoanut oil soap is by far the best for this purpose since of all known soaps it takes up the greatest amount of water, up to its own weight or more, without losing its firm consistency. I therefore confined my subsequent experiments to it.

It soon appeared that the cocoanut oil soaps on the market gave variable results. I therefore began making my own soap. The results were very much better than with any commercial soap which I have been able to obtain, and since the soap is easily made it is by all means advisable to manufacture it for one's self. It is only necessary to mix cocoanut oil with a watery solution of sodium hydrate in suitable proportions and stir the mixture for a few moments, either in the cold or on a hot water bath, to produce a good soap.

The proportion of cocoanut oil to soda necessary to produce a soap without "free alkali" is 70 c.c. of oil* to 38.5 c.c. of 28%

*The oil is practically constant in composition.

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solution of caustic soda in water. It is advisable to have a slight excess of oil present.

In practice I have found it advisable to warm the cocoanut oil in a water bath and then add the lye gradually, stirring all the time. In a few minutes the soap begins to harden and soon becomes quite firm. It may then be allowed to stand until needed for use.

For the purpose of embedding the tissue it is placed in water (if air is present in the tissue it may be removed by means of the air pump described on page 78 of this volume) and heated on the water bath. The soap powder is then added, a little at a time, until a fairly strong solution is formed. If necessary this may be allowed to stand for some time in order to give the soap an opportunity to penetrate. Ordinarily, however, this may be dispensed with in the case of algæ, and after adding as much soap as will dissolve the whole may be poured into a suitable receptacle and allowed to stand in the bath until sufficiently firm to cut. This takes at the most from two to three days.*

Owing to the fact that the mass shrinks considerably during this time it should be placed in a deeper receptacle than is ordinarily used for paraffin (a glass vial, paper box or deep paraffin moulds may be used.)

When sufficiently firm the block may be trimmed and used at once or it may be preserved indefinitely by dipping it several times in melted paraffin so as to hermetically seal it against further evaporation. A number of blocks may be thrown in melted paraffin on the bath and the whole embedded in a single, large paraffin block whenever convenient. I have frequently left the soap blocks in melted paraffin for days without any deterioration and for certain purposes I am inclined to think there may be a decided advantage in this method of treatment.

The soap blocks may be cemented to the holder by means of melted paraffin and cut in the same manner as paraffin blocks. The cutting properties of the soap are far superior to those of paraffin. Perfect ribbons, one micron in thickness and several

*If necessary the use of heat may be dispensed with and the whole process carried on in the cold.

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feet long are easily obtainable. When the mass is of the proper consistency—and this is very easy to obtain with a little experience—there is no crumpling or crushing of the sections such as so commonly occurs with paraffin. The sections adhere perfectly to form a ribbon, except when through carelessness the mass has been allowed to become too dry on the surface. The easiest way to remedy this is to dip it in paraffin until well coated, or if the block is large enough it may be retrimmed. The ribbons may be preserved in the same way as paraffin ribbons.

The further treatment of the sections depends upon the object in view. They may be fastened to the slide in the same way as paraffin sections by a modification of the water-albumen method (using xylene in place of water) or by the ordinary albumen or Schällibaum methods. Since these involve the drying of the sections they are undesirable in the case of delicate algæ. These are not sufficiently altered by the soap-and-water process to prevent them from resuming their original proportions when placed in water and for many purposes it is highly desirable that this be done. The simplest plan is to place the sections in a watch glass with water, which dissolves off the soap. They may then be handled in the same way as fresh or frozen sections. They may be fastened to the slides by any of the methods available for watery sections (see Lee's Vade Mecum, 4th ed., p. 128).

In order to preserve the serial order and fasten the sections to the slide the following method was used: the ribbons are placed on the slide, which has previously been well coated with pure white of egg and then dried; they are moistened with xylene, which causes them to spread out and adhere to the slide. A piece of soft absorbent muslin is then laid over them and pressed down gently upon the sections so that the xylene moistens it and causes it to remain in place. As soon as the xylene has all evaporated a drop or two of water is cautiously placed on the cloth. This at once spreads, dissolving the soap and swelling the sections out to their original proportions without allowing them to leave their places. The slide is now cautiously heated until the albumen coagulates and fixes the sections to the slide. A few more drops of water are

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placed on the cloth, and it is cautiously removed by raising one end first. It sometimes happens that the sections adhere to the cloth: this may be prevented by rubbing the cloth with a piece of paraffin to make it less adhesive. If the sections fail to adhere properly to the slide more albumen should be used. Instead of heat a solution of chromic acid (or a combination of both) may be used to coagulate the albumen.

The sections may now be treated in the usual manner, and if the fixation has been properly done they may be placed in alcoholic or watery stains without danger. They can also be dehydrated without shrinking, since their firm adherence to the slide prevents any change of shape. They may be mounted in glycerine jelly or balsam.

Alcohol may be used in place of water for the purpose of embedding, and in many cases gives excellent results. The tissue is partly dehydrated, preferably by means of a dehydrator,* and then placed in alcohol on the water bath. The alcohol used is usually from seventy to ninety-five per cent. Soap is added until no more will dissolve: the solution is then allowed to remain on the water bath until of the proper consistency. This takes place in a few minutes if strong alcohol is used and the temperature of the water bath be above the boiling point of the solution. It should be remarked that in this, as in the water method, cocoanut oil soap is much superior to all others.

While the method here described has been used principally with plant tissues, and especially with delicate algæ, it has also been tried on animal tissues with striking success. Its merits may be summed up as follows:

1. It has the advantage over the freezing method that it makes much thinner sections to be made (down to one micron), and gives serial sections.

2. It is superior to the paraffin method in point of quickness (requiring 2-3 as against 9-10 days): it cuts much better than paraffin and does away with crushed and crumpled sections; it preserves the tissues (especially of delicate algæ, etc.) in much more nearly their natural condition so as to give entire satisfaction where paraffin cannot be used at all.

* Described in *Flora*, Bd. 87, p. 109. 1900.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BOTANY

Vol. 2, No. 3, pp. 91-113 April 12, 1905

LIMU

BY

WILLIAM ALBERT SETCHELL

BERKELEY

THE UNIVERSITY PRESS

PRICE $0.25

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LIMU.

BY

WILLIAM ALBERT SETCHELL.

The Hawaiian word "Limu" signifies seaweed and is used in both a more limited and a more extended sense. In the more narrow sense, it is restricted very nearly to what the botanist knows as Algæ, including, however, at times, certain lichens and certain of the more delicate aquatic Phænogams. In the more extended sense, it included besides, as was gathered from several native sources by word of mouth, even motionless or sessile animals, such as certain Ascidians, Corals, etc., following the example, as it were, of the earlier botanical writers. The present use generally indicates algæ which are edible or used in some ceremony or custom which is a relic of past superstition or observance. The names given to the varieties of limu are considerable in number and are difficult to obtain from the younger members of the native population. The younger natives have either forgotten all except a very few, or else, they apply them erroneously, as the writer has had occasion to note. The older women, and occasionally an older fisherman, have a considerable knowledge, and in some cases such knowledge is at the same time broad and discriminating. The investigator who does not know some little of the Hawaiian language generally finds it difficult to obtain any knowledge whatever, since the Hawaiians best informed about limu often speak but little English and are shy in talking with strangers. The writer found that when once he had made a beginning in native names the process was more easy and more certain, even though his Hawaiian vocabulary was lamentably limited.

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The native population eat the limu, and almost entirely the raw and fresh limu, and one may see the women gathering material at many places where the coast is sufficiently rocky to support algal life, and when the tide is low enough to enable them to wade out and gather it. Such collectors may furnish very considerable information, if they can be approached in the right way and induced to talk freely. In the fish markets, again, one may find limu exposed for sale, especially if he can find out on what days and at what hours it is to be expected. Sometimes there is some variety in the limu exposed in the fish markets, while again it may be only a certain stock species, which, however, will vary with the locality. All depends upon the time of the return of the fishermen. Limu, with their proper kinds of limpet, sea egg, or shrimp, are to be found at every native feast or "luau." Rev. C. M. Hyde, in the Hawaiian Almanac and Annual for 1886, when speaking of ferns, says: "To a genuine Hawaiian a feast is not a regular *luau,* as foreigners call such festivals, without the presence of these dryads of the mountains, and as lovingly do they rejoice also in bringing to their feasts those nymphs of the sea, the *limu* (sea mosses), some of which, like the *lipoa,* have become to the Hawaiian the synonym of the most delicious fragrance." The foreigner, as a rule, hesitates to eat raw seaweed, but when he trys the unaccustomed food he finds a variety of flavors and a relish in some of the species which amply repays him for his courage in making the attempt.

Not only do the Hawaiians eat limu of various sorts, but they are very particular in their selection, and especially esteem, for flavor, those of certain kinds from certain localities. As will be indicated below, I learned from a fisherman of Lahaina that there were specialties in limu, and that while a certain kind obtained in most places might be unpalatable or tough, or in some other way undesirable for eating, when growing in some particular and apparently well-known locality, was highly esteemed, or some other universally eaten species was especially delicious in some particular locality. The connoiseurs in limu appear to distinguish them gastronomically as would the expert in the flavors of oysters or wine.

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The writer spent the month of July and a few days of August, 1900, in the Hawaiian Islands, visiting the shores principally in the neighborhoods of Honolulu and Hilo. His chief attention was paid to the names and uses of the limu, although many species were gathered of algæ concerning which nothing could be learned. At first it was impossible to learn anything, and the first few inquiries either elicited the response that the specimens had no names, or that the Hawaiian did not know the name. In order to show the sources whence information has been drawn, and to make more clear what credence is to be given to the statements made below, it will be well to state the writer's experiences in what was to him a new occupation.

The first names were obtained at Hilo. I noticed that native women and children were collecting a coarse, hair-like limu in some quantities, and inquired the name and use. My inability to understand the name given by several persons was natural, in the first place on account of my lack of familiarity with Hawaiian sounds, and in the second place on account of the complexity of the name of this particular limu, which was *hulu-huluwaena.* Later, I became very familiar with this sound, because I heard it often, and I was instructed how to sound every vowel and say it both slowly and rapidly. I also learned to know the limu which passes under the name of *akiaki.* With the exception of these two species, I was unable to find out anything more about limu, but was told that there were many more eaten in Honolulu, and was given several names to ask about when I should return to that city.

Through the kindness of Samuel Peck, Jr., then of Hilo, whose guest I was, I was enabled to make an excursion to the coast of the district of Puna, not far from Pohoiki, where we were the guests of Hon. R. A. Lyman and family, who did all they could to help me in my search. A short visit to the coast procured a number of species of algæ, some of which were known to Mrs. Lyman. To help in the work, Mrs. Lyman very kindly made arrangements for me, with the wife and daughters of a native clergyman, to collect and name as many limu as they could procure. Such a collection was later forwarded to me, and has been of great help.

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With Mr. Peck and my companion, Mr. L. E. Hunt, I also made a trip to Laupahoehoe, and found many algæ on the bold point which is well known to all visiting that coast. In the early morning, at a very low tide, I found several women collecting limu, one of whom told me a number of names, confirming some that I already had and adding others. One or two other Hawaiians at the wharf also gave me some information.

On the return trip to Honolulu I was fortunate enough to meet Mr. J. S. Emerson of the United States Coast and Geodetic Survey, who has great knowledge of, and facility in speaking, the Hawaiian language. He offered to assist me by acting as interpreter, and it is through the more exact information gained from and through him that I have been able to make any satisfactory headway. He accompanied me ashore during the wait of the steamer at Kawaihae and questioned a group of fishermen, among whom were some older ones, whom we found upon the wharf. The answers from the old men of this group first gave me a real idea of the subject. When the steamer was under way after leaving Lahaina, Mr. Emerson told me that he had noticed an elderly fisherman come aboard at that place, and suggested that we go down to the steerage and see if he could give us some information on limu. We found a very pleasant and obliging man, named Mohokini, then in his sixty-eighth year. He answered many questions and explained in many instances how the same plant was called by a different name, according to whether it was found in Hawaii, Maui, Molokai, Oahu, or Kauai. The other native passengers occasionally put in a word or exploded with mirth at some question which seemed to them to be unusually ludicrous, or perhaps furnishing some play on words usually unintelligible even to Mr. Emerson.

In Honolulu, on my return, I visited the fish market frequently, and found a number of species more or less regularly placed on sale. From the vendors I was able to find out something, but not much.

In the fisherman district of Honolulu, called Kakaako, I found, on my first visit, a boy who professed to know limu, and engaged him to collect and name some for me. He brought me quite a number, some of which he seemed to know all right, but

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to others he gave names in which I place no credence, especially as some of them have sounds not found in pure Hawaiian. In the same locality, however, I met a middle-aged fisherman, named John Poai, who did assist me greatly. He made one considerable collection himself and brought it in. When I came down to look at the specimens he assembled a number of old men and women to do the naming, saying that he did not know the names himself. I picked up one limu after another and handed them to him. He would pass them about the circle. The Hawaiians would look at them, smell them, taste them, and hold a great discussion over them in Hawaiian. Finally, Poai would tell me what the names were, and could even tell me whether I had spelled them correctly, although by this time I had become sufficiently acquainted with Hawaiian sounds to hit the spelling correctly. These people also named for me a collection I made myself at Waikiki.

The two sources among printed materials, known to me, for Hawaiian names of limu, are those given under "Limu" in Andrews's Dictionary of the Hawaiian Language and those given in J. B. Chamberlain's "Algæ of the Hawaiian Islands."

From all these sources I have learned many names and many things concerning the uses and ideas about limu. First, however, it seems to me best to say some things about limu in general which have come to me from the different conversations I have held with the fishermen.

Mohokini divides limu into two classes. In the first, he places those which will keep in condition for eating for a long time, such as a year, or even a little longer. In the second class, which he calls "one day limu," he places all the rest, saying that they must be eaten the same day that they are gathered. All the fishermen agree that limu are eaten raw, cooking being exceptional. Occasionally some kind of limu is boiled with fish or shrimps, so as to dissolve and form a jelly when cooled, or is used to wrap about a pig or dog when cooked underground, when those portions smeared with fat or drippings are much esteemed. There seems to be a certain association of certain limu with particular food, such as huluhuluwaena with the limpet called opihi, manauwea with fresh squid, etc. I could not find any recollection of

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any limu being used for medicinal purposes, and heard of only one with a reputation for being poisonous, as will be mentioned below under Mualea. One species, Limu kala, or Atonement Limu, is used ceremonially, and I have seen a child with a lei of this limu on its head. What other special items of information came to my knowledge in the course of the investigation will be given in the list of names of limu given below.

LIST OF LIMU.

In the following list I have brought together all the Hawaiian names applied to algæ, together with mention of the sources of information, derivations wherever possible, notes on use, etc., as completely as they could be discovered by me.

AALAULA. Aalaula is said by Mohokini to be the Hawaii-name of a seaweed which is known in Maui under the name of *Peepee.* He also says that it must be eaten in the same day in which it is gathered. The name is given in Andrews's Dictionary as *Limuaalaula.* The Kawaihae fishermen said that the name means fragrant and red or dark, and that the limu is found generally throughout the islands. I was told by some natives in Hilo that *Aalaula* was a favorite in Honolulu. At Honolulu the old fisherwomen, as interpreted by John Poai, applied this name to a species of Codium which Mr. Collins determines as *Codium Muelleri* Kuetzing. Poai says that some forms of this species are also called *Wawaeiole,* or "Ratfoot," as noted below. It seems also that *Alaalaula* and *Alaula* are simply different forms of the same word, or, at least, applied to the same forms, as will be seen below.

AKIAKI. A species of Ahnfeldtia, which is both coarse and firmly cartilaginous, is commonly eaten in the island of Hawaii, and called Akiaki. The Kawaihae fishermen say that it is eaten with Opihi, a kind of Limpet, and that it is also called *Koeleele.* Mohokini says that *Akiaki* and *Koeleele* are Hawaii-names for the same plant, which is also found on the Island of Maui, but is there called *Ekahakaha.* This limu is known in Puna also, under the name of *Akiaki,* as shown by the collection named by the family of the native clergyman mentioned above. The name means to bite repeatedly, or to crunch—a very appropriate name

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for this species. As to the identity of the plants included under *Akiaki* and *Koeleele,* my own experience differs from the statements made above, as may be seen below under the latter name. The species may be named *Ahnfeldtia Polyides* Aresch., which is probably only a form of *A. concinna* J. Ag., which, in turn, probably also includes *A. Gigartinoides* J. Ag.

Andrews does not place *Akiaki* in his list under the word Limu, but elsewhere (p. 43) he says: "Name of a species of seaweed adhering to the rocks; it is eaten for food." Chamberlain mentions it in his list as "Limu akiaki."

AKO'AKO'A. According to Andrews, this name refers to coral in general, and to the horned coral in particular. John Poai told me that it is applied also to limu which, from his description, I think is one, or perhaps includes all, of the jointed corallines.

ALAALAULA. Limu alaalaula appears in Chamberlain's List, and seems to come from *alaala,* meaning soft and tough, and *ula,* meaning dark or red, two words readily understood as perhaps applying to Codium.

ALANI. Limu alani is found mentioned in Chamberlain's List. *Alani,* according to Hillebrand (Flora of the Hawaiian Islands, p. 61) is a name also applied to species of *Pelea,* a genus of *Rubiaceae.* All of the species of *Pelea* have a spicy odor. Poai tells me that *Limu alani* is the same as *Limu make.*

ALAULA. This is probably only a form of *Aalaula* and means the same, *i.e.,* fragrant and dark colored. A specimen collected and named this by the family of the native clergyman at Puna, is *Codium Muelleri* Kuetzing.

AUPUPU. Limu aupupu is mentioned in Chamberlain's List. The name may come from *au,* meaning swimming, and *pupu,* either meaning rough, or a contraction for *puupuu,* meaning swollen.

EHAU. Limu ehau is found mentioned in Chamberlain's List.

EKAHA. Limu ekaha is listed by Andrews under Limu. Poai attaches this name to *Halimeda* species, found in the neighborhood of Honolulu. Under the word *Ekaha* Andrews has: "Name of a hard kind of bush which grows in the sea." He also says that the name refers to a parasitical plant and a fern-like plant.

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EKAHAKAHA. According to Mohokini, this is the Maui-name for the plant (or plants) called in the Island of Hawaii by the names *Akiaki* and *Koeleele*. *Limu ekahakaha* is listed by Chamberlain.

ELEAU. Mohokini is responsible for this name. According to him, it is to be found at low tide, in a zone just above the water. It is one to two feet long, and is used as a substitute for banana leaves in cooking pig in native fashion. It is eaten only after it has taken part in such cooking, and only such parts of the limu are eaten as are smeared with particles from the cooked pig.

ELEELE. Usually, in speaking of the various kinds of limu, the natives use simply the special designation, but in a few cases they always prefix the word limu. This is the case with *Limu eleele,* which occurred to me most frequently in my brief experience. The compound form was always used. *Limu eleele,* although to me the least attractive limu of all, seemed to be the most sought after and the best known. Curiously enough, however, the name is not mentioned in connection with limu by either Andrews or Chamberlain. The natives, when questioned about kinds of limu, always spoke of *Limu eleele,* and I frequently found that the native women were collecting that species and no other. The Kawaihae fishermen told me that *Limu eleele* was eaten with anything. I found it constantly in the fish market at Honolulu. Mohokini told me that it is the favorite limu in Lahaina, that it is found growing in running water, fresh or brackish. He said the fresh-water form keeps only two days, while the salt-water form keeps a week. He described it as slippery and fragrant. He even declared that one can smell it, even from the steamer in passing, in a district called Puakoolau, on Molokai. I obtained *Limu eleele* from several sources, and the specimens all belong to forms of *Enteromorpha intestinalis* (L.) Link.

HINAULA. Andrews gives *Limuhinaula,* and Chamberlain, probably copying from him, lists *Limu hinaula.* Beyond these two references I have been unable to obtain any information.

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HOLOMOKU. Chamberlain lists *Limu holomoku.* Andrews gives *holomoku* as meaning sailor.

HONA. Poai applied the name *Limu hona* to a seaweed determined by Mr. Collins as *Hypnea nidifica* J. Ag. He afterward applied the name *Limu huna* to the same species, as may be seen under *huna* below.

HOONUNU. This name was applied to a specimen of *Laurencia obtusa* var. *racemosa* Kuetzing by the family of the native clergyman in Puna.

HUAHUAKAI. Chamberlain gives *Limu huahuakai* in his List. Andrews says that *huahuakai* means a sponge.

HULUHULUWAENA. This was the first native name of any limu which I learned. I found it in common use in Hilo, eaten with the limpet called *Opihi.* The flavor is pleasant, even to one unaccustomed to eating limu. In Hilo I frequently saw native women gathering it and carrying it home by the pailful. I met it again in Puna and at Laupahoehoe, both on the Island of Hawaii. It is coarse, black, and hair-like. All the specimens were *Grateloupia filicina* (Wulf.) Ag. Mohokini says that the Maui-name is *Pakaeleawaa.* The name *Huluhuluwaena* seems restricted to the island of Hawaii, as well as the use of this limu. The Kawaihae fishermen, in fact, told me that it was found only in Hilo, on the Hamakua side. While this is not strictly true, I found the name unfamiliar in the other islands, and while questioning Mohokini about it on board the steamer, the mention of the name aroused some merriment among the passengers, the reason for which did not at that time appear either to Mr. Emerson, who was interpreting for me, or to myself. The derivation seems to be from *huluhulu,* meaning hairy, and *waena,* meaning the middle, and I was assured later by a young man who had lived all his life among the natives that the whole word means the *pubes.*

HULULIO. Andrews gives *Limuhululio,* and Chamberlain *Limu huluilio.* A specimen collected and named *Huluilio* by the family of the native clergyman at Puna has been determined by Mr. Collins as *Jania rubens* (L.) Lam'x.

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HUNA. Andrews gives *Limuhuna*, and Chamberlain *Limu huna*, while Poai applies the name *Limu huna* to a plant determined by Mr. Collins as *Hypnea nidifica* J. Ag. As stated above, Poai applied (and spelled it out) the name *Limu hona* to another specimen of the same species, which, however, differed slightly from this one in general habit. Poai says that the natives stew *Limu huna* with meat.

HUNE. Chamberlain lists *Limu hune*. Perhaps this may be the same as the *Limu hona* or *Limu huna*, mentioned above.

HUNEHUNE. This is another name in Chamberlain's List—*Limu hunehune*—which cannot at present be traced any further.

HUWAE. This name, or perhaps spelled *Huwai*, was applied to an expanded species of Codium by John Poai. The Codium seems to be near to, if not identical with, *Codium spongiosum* Harvey.

ILIOHA. Andrews defines this word (p. 78) as "a species of limu having broad leaves; he limu lau palahalaha." It is probably a name for some form of Ulva, and used much as the names *Pakaiea* or *Palahalaha* are.

KAHAKALA. This name is given by Andrews under *Limukahakala*, and by Chamberlain under *Limu kahakala*. *Kala* means rough, while *kaha* is a name for cloth.

KALA. This is another name which is always prefixed by the word Limu and spoken *Limu kala*. Andrews gives *Limukala*, and Chamberlain *Limu kala*. The word *kala*, according to Andrews and others, means to loosen or to untie, hence comes to mean forgiveness and atonement. Alexander (W. D.) speaks of the use of *Limu kala* in the ceremonies of purification (cf. A Short History of the Hawaiian People, p. 54.), and from the stories gathered and related below, this use in ceremonies of purification and atonement was not confined to general and public ceremonies, but also was extended to cases purely personal. The Kawaihae fishermen said that *Limu kala* is used for two purposes, viz.: first, for food; second, for getting atonement, religious, not moral. The one who has sinned gets all persons concerned together, makes a prayer, and then throws the limu from him. It

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takes with it all the sins. Mohokini says that the *Limu kala* has the same name on Maui as on Hawaii. He further says that it is eaten, and that when a kahuna has treated and cured a patient he has the patient bathe, put *Limu kala* in his mouth, spit it out, and then put a lei of *Limu kala* on his head. This is symbolic of being healed. I have seen a child with a lei of *Limu kala* on her head, but failed to find out whether any significance was attached to its presence. Every native questioned knew about *Limu kala*. The Kawaihae fishermen assured me that there was only one kind of limu passing under this name. Some natives said that it was not "kaukau," or edible, while others, particularly the woman at Laupahoehoe, said that it was eaten. She applied the name equally to species of Sargassum and of Turbinaria. The specimen given to me by John Poai is *Turbinaria ornata* J. Ag., while a specimen labeled *Limu kala* by the family of the native clergyman at Puna is *Sargassum echinocarpum* J. Ag., both determinations being by Mr. Collins. The Hawaiian name, then, like other limu names, is general rather than special, applying probably to all members of the Sargassum group.

KALALAULIILII. In Chamberlain's List there are two names, this one and the next one, which seem to refer to the *Limu kala* and to distinguish between two kinds, although the seaweeds themselves are unknown to me and the evidence is purely philological. *Limu kalalauliilii* may be divided into *Limu kala lau liilii,* and may mean the *Limu kala* with the small leaves, *lau* meaning leaf and *liilii* meaning small. It is to be compared with the next for further evidence as to its application.

KALALAUNUINUI. Chamberlain has *Limu kalalaunuinui*. Comparing this with the preceding, we may divide this name into *Limu kala lau nuinui,* or the *Limu kala* with the large leaves, *lau* meaning leaf, as above, while *nuinui* means large. It seems, perhaps, that the reference in these two names may be to species of Sargassum. *Sargassum echinocarpum* has large and rough leaves, and there are two or more species of Sargassum fairly common in Hawaiian waters whose leaves are small, at least, by comparison.

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KAUNOA. John Poai applied the name *Kaunoa* to specimens of *Galaxaura rugosa* (Solander) Lam'x., as determined by Mr. Collins. According to Andrews, the name is applied to "a slender worm which when it comes upon a tree or herb, there is a universal withering," and also to "the dodder, a parasitic plant." The application here is probably derived from the similarity in shape between these objects and the Galaxaura.

KELE. Andrews has *Limukele,* and Chamberlain has *Limu kele.* The name was unknown to any of the natives whom I had an opportunity of questioning.

KIKALA. John Poai applied this name to specimens of *Centroceras clavulatum* (Ag.) Mont., as determined by Mr. Collins.

KIKI. Andrews has *Limukiki,* and Chamberlain has *Limu kiki. Kiki* is a frequentative and intensive of *ki,* to shoot or squirt, according to Andrews, and is defined as meaning "to spurt, as water pressed through a small orifice." The name may be applied to some alga which is filled with water and which "spurts" it out on being pressed.

KOELEELE. Chamberlain lists this limu under the name of *Limu koeleele,* and the name seemed to be known to most of the natives with whom I had any chance of conversing on the subject. I have three collections under this name, all of the same alga. John Poai named some of the Honolulu specimens by this name; the family of the native clergyman at Puna, and the woman at Laupahoehoe also gave me specimens of *Koeleele,* using the name without limu prefixed to it. All these specimens are the same, and are young or perhaps rather dwarfed plants which look much like a young Chondrus. Chamberlain mentions *Chondrus affinis* in his list as being found in the Hawaiian Islands. Careful sectioning and comparison with other forms leads me to believe that *Koeleele* is simply a dwarfed and undeveloped form of a Gymnogongrus, which seems to agree fairly well with the description and figures of *G. vermicularis* f. *Americana* J. Ag. The Kawaihae fishermen and Mohokini both told me that the name applies to the same limu as *Akiaki,* but that name, according to my own experience, is always applied to the coarse Ahnfeldtia of the coast of the Island

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of Hawaii. *Koeleele,* however, is to be translated the same as *akiaki, i.e.,* to mean *crunching,* and that is perhaps what my informants had in mind.

KOHU. This name is always spoken in the form of *Limu kohu,* and while it has been mentioned to me or has been known to most of the natives with whom I have spoken, it is not given by either Andrews or Chamberlain. The word *kohu* means "to color or stain," and certainly this limu does leave a stain on the paper on which it is dried. A specimen given to me by the woman at Laupahoehoe has been determined by Mr. Collins as *Asparagopsis Sanfordiana* Harv. I found this limu, under this name, in the fish market at Honolulu. It was sold in the form of globular masses, each about the size of a baseball, made up of the fronds of the Asparagopsis compacted together and mixed with salt. A specimen bought there kept well for somewhat over a year. The Kawaihae fishermen told me that *Limu kohu* and *Limu koko* are names for the same plant, which has a peppery flavor. Mohokini told me that *Limu kohu, Limu koko,* and *Lipaakai* are all names for the same plant, the last being the name in use on the Island of Maui. He said that this limu is pounded, mixed with salt, and eaten with fresh fish. He classed it as a "one year limu."

KOIALE. *Limu koiale* occurs in Chamberlain's List.

KOKO. Andrews has *Limukoko,* and Chamberlain *Limu koko.* There is a general agreement that it is the same as *Limu kohu.* A specimen named *Limu koko* by the family of the native clergyman at Puna is a soft, young form of some species of Laurencia, looking, however, something like *Asparagopsis Sanfordiana* Harv.

KOLOA. Chamberlain lists *Limu koloa.* Andrews says of the word *koloa* that literally it means "long cane," and that "this fact of long cane is said to have given a name to a district on Kauai."

KUKAEPUEO. Andrews says that this name is applied to a species of grass, and also to a species of seaweed. *Kukae* means excrement or filth, and *pueo* means owl.

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KULAPEPEIAO. A specimen, apparently a distorted *Gracilaria coronopifolia* J. Ag., was named this by the family of the native clergyman at Puna. The name means "earring," literally "ear-gold," and was probably applied to this specimen on account of the peculiar distortion.

KUMULIMUKALA. Chamberlain has the name *Limu kumulimukala.* An examination of the word shows that *kumu,* when applied to plants, generally means "the lower end or stump." Possibly the name quoted means the lower ends or stumps of *Limu kala.*

KUMULIPOA. This is found also in Chamberlain's List in the form of *Limu kumulipoa.* Comparing the form of this word with the form of the last, it may mean the bases or stumps of *Lipoa,* the last word being applied to algæ belonging to the Dictyotaceæ, as may be seen below.

LIPAAKAI. Mohokini says that this is the Maui-name for *Limu koko* or *Limu kohu* and, consequently, the plant is *Asparagopsis Sanfordiana* Harv. Mohokini classes it as a "one year limu," and says that it is pounded up, mixed with salt, and eaten with fresh fish. The name means "salt limu." *Paakai* means "salt." The prefix seems to be a contracted form for *limu,* as may be gathered from examining a number of names for seaweed which begin in *Li-*. Both Andrews and Chamberlain, however, prefix the word limu even to such names. Mohokini, in turn, says that *Limu* is not prefixed to *Lipaakai,* and says also that the word means "salt limu."

LIPAHA. Andrews says: "*Lipaha*—He wahi limu. See LIMU, sea-grass." I understand by this that *Lipaha* is a synonym for *Limu,* but it seems to me, from the structure of some of the following forms, that the *limu* idea is conveyed by the *li-,* while *paha* probably conveys an additional meaning of broad, the name, then, being confined to the more expanded forms of seaweed. The suggestion is put forward here for others with more favorable opportunities for solving the question.

LIPAHAPALA. Andrews gives *Limulipahapala,* and Chamberlain writes the name *Limu lipahapala.* We find here the prefix *li-,* and the question arises, as in the last case, does *li-* stand here

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for a contraction of the word *limu?* We may consider two sets of combinations—either *Lipaha* and *pala,* meaning soft limu; or *Li-, paha,* and *pala,* meaning the broad, soft limu.

LIPAHEE. According to Mohokini, *Lipahee* is a seaweed found on Maui, and is the same as the one called *Pahee* on the Island of Hawaii. The derivation may be *li-* and *pahee* meaning smooth, polished, or slippery.

LIPALAHALAHA. Mohokini gives this name as the one used in Maui to designate the seaweed known as *Pakaiea* on the Island of Hawaii. The name is one of several referring to species of Ulva and Monostroma, broad, membranous, green seaweeds, known to English speaking peoples as "Sea-lettuces." Here the *li-* evidently stands for *limu,* while *palahalaha* is given by Andrews with the meanings of (1) broad, and (2) "a species of limu."

LIPAKAI. *Limu lipakai* is given in Chamberlain's List. It is probably a contraction for, or perhaps even a misprint for *Lipaakai,* the "salt limu," or *Asparagopsis Sanfordiana* Harv. It is susceptible of another interpretation, if we take *li-* to mean *Limu* and *pakai* to mean a vegetable.

LIPALAO. The *Limulipalao* of Andrews and the *Limu lipalao* of Chamberlain may refer to some seaweed eaten with a particular kind of fish, for, if we take *li-* to represent seaweed, we find that *Palao* is the name used for a certain kind of fish.

LIPALAWAI. We find this name in the form *Limulipalawai* in Andrews, and *Limu lipalawai* in Chamberlain. They have also *Limupalawai* and *Limu palawai,* according to their different ways of writing these names. *Lipalawai* is apparently made up of *Li-* and *palawai,* the latter meaning running fresh water. Mohokini says that it occurs in running fresh water, very little of it now to be had at Lahaina, but at Honokahau, on Maui, where there is a large stream of water, there is some. The Kawaihae fishermen say that it is found in running fresh water, that it is edible, that it extends down into brackish water, and is dark greenish brown. Some further information may be found below under *Palawai.*

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LIPALU. This name is given to a specimen collected and named by the family of the native clergyman at Puna. It is one of those young plants of a species of Laurencia so much in favor with the natives as an article of food. The name is probably composed of *li-* and *palu,* meaning soft seaweed.

LIPEEPEE. This is one of the species of limu classed by Mohokini as a "one day limu." The name is applied by John Poai to young and tender plants of Laurencia, usually not to be determined as to species. In one set of Poai's specimens, however, the plants undoubtedly belong to *Laurencia obtusa* var. *racemosa* Kuetz. A specimen collected and named by the family of the native clergyman at Puna proves to be *Amansia glomerata* Ag. I incline to the belief that the name is usually applied to young Laurencias, which have a slightly peppery flavor.

LIPEHU. The name *Limu lipehu* appears in Chamberlain's List. The derivation may be from *li-,* and *pehu* meaning swollen.

LIPEWALE. I find this name only in the *Limu lipewale* of Chamberlain's List.

LIPOA. All my informants agree that this is an especially esteemed species and much sought after. The Kawaihae fishermen say that it is fragrant, pleasant to the taste, and is found in Kohala, on Hawaii, and in Lahaina. Mohokini says that it keeps a year, and is treated in the same way as *Lipaakai.* The name is applied in general, I think, to the Dictyotaceæ, but especially to *Haliseris plagiogramma* Mont. John Poai gave me a specimen of *Dictyota divaricata* Lam'x. with this name, but said that it was not the "strong kind." Charlie Cook gave me a specimen of *Dictyota dichotoma* (Huds.) Lam'x., and also one of *D. patens* J. Ag., both of which he called *Lipoa.* The common kind of *Lipoa* is evidently *Haliseris plagiogramma.* Every afternoon I found this in the fish market of Honolulu. A small bunch of this species was given with every three flying-fish sold, much as parsley is given with fish elsewhere. The odor of the real *Lipoa,* which, as quoted above, has become the "synonym of the most delicious fragrance," is like that of a very strongly smelling parsley. I have been told that it was customary on the mule-trams in Honolulu to make the women place their pails or bundles

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of limu outside on the platforms of the cars, because of the strong odor of this species.

As far as I could find out, *Limu* is not prefixed to this name in speaking, but Andrews has *Limulipoa* and Chamberlain has *Limu lipoa,* an unnecessary duplication if *li-* proves to be, as I suspect it is, a contraction for *limu.* Additional evidence that the *li-* of *Lipoa* and similar words is a contraction for *limu* is to be found in the words *Kumulimukala* and *Kumulipoa* noted above. In the first, it is to be noticed that *Limukala* is given in full, while in the second only *Lipoa* is given.

LIPUPU. Andrews has *Limulipupu,* and Chamberlain has *Limu lipupu.* The derivation may be from *li-* and *pupu,* rough, or from *li-* and *pupu,* a contraction from *puupuu,* meaning swollen.

LIPUULA. This name occurs in Andrews's Dictionary as *Limulipuula,* and in Chamberlain's List as *Limu lipuula.* The derivation may be *li-, pu,* meaning swollen, and *ula,* meaning dark.

LIPUUPUU. This name is given both by Andrews and by Chamberlain, in their respective styles, as *Limulipuupuu* and *Limu lipuupuu.* The name seems to come from *li-* and *puupuu,* swollen. In Puna the name was several times applied to young and tender specimens of some species of Laurencia, but I think it was confused with *Lipeepee.* John Poai applied the name to a specimen of *Dictyosphaeria favulosa* (Mert.) Decaisne, which is certainly swollen. A woman selling limu in the fish market at Honolulu was at first inclined to call a specimen of the Dictyosphæria *Aalaula,* but after thinking and consulting with some fishermen, called it *Lipuupuu.* Mohokini classes this limu among those which will keep only one day.

LOLOA. Andrews has *Limuloloa,* and Chamberlain *Limu loloa.* The derivation seems to be from *loloa,* meaning long. A specimen named for me by a woman collecting limu at Laupahoehoe is a young Gelidium which Mr. Collins thinks may be *Gelidium Amansii* Lam'x.

LUPE. Chamberlain lists *Limu lupe.* Andrews says that *lupe* is synonymous with *Hihimanu,* "a large, broad, soft living creature found in the sea; it was forbidden to women to eat under penalty of death." *Lupe* also means a kite and a kind of fish.

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MAKALOA. *Limu makaloa* is found in Chamberlain's List. *Makaloa* means always green or fresh.

MAKE. This name was mentioned to me by John Poai, who said that it was the same as *Limu alani*. *Make* means death.

MANAIEA. This is defined by Andrews as "a species of sea moss." He also says "See *Manauea,*" but I fail to find this latter word in his Dictionary.

MANAUEA. As given above, Andrews refers to this name under *Manaiea*. A specimen collected and named *Manauea* by the family of the native clergyman at Puna has been identified by Mr. Collins as *Gelidium filicinum* Bory.

MANAUWEA. This may perhaps be synonymous with *Manaiea* and *Manauea*. Mohokini *classes Manauwea* as a "one day limu," to be eaten with fresh squid, not with salt squid. He says one may cook the limu or not. If it is boiled it dissolves, but on cooling it becomes solid again. Charlie Cook, a boy at Kakaako, applied this name to a specimen of *Gracilaria coronopifolia*, but I place little confidence in his determinations. It may be that the *Limu mauauwea* of Chamberlain's List is simply a misprint for this name.

MANEONEO. This is the *Limu maneoneo* of Chamberlain's List. Mohokini says that *Maneoneo* grows with *Lipeepee* at Lahaina, and that it keeps only one day. John Poai identifies as this limu a specimen determined by Mr. Collins as *Laurencia obtusa* var. *racemosa* Kuetz.

MAUAUWEA. The *Limu mauauwea* of Chamberlain's List, as suggested above, is probably only a misprint for *Limu manauwea*.

MUALEA. While in Honolulu, but just as I was about to leave for San Francisco, I heard repeatedly of a limu reputed to be extremely poisonous. I can only give the unsatisfactory evidence gathered so far, leaving the further investigation to someone who is closely in touch with those who may know about it. I first heard of it from Mr. Vincent of Honolulu, who told me that a poisonous limu, of which he did not know the name, grew at Kipahulu, near Hana, on Maui. He described it as a curly and greenish limu, so poisonous that one cannot pick it up with the

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hand. If placed upon a hot stone it melts. If it is dried and some placed in Awa, one who drinks it will die in fifteen minutes. When dried it is reddish, and is much stronger than when fresh. Mr. Pierre Jones of Honolulu told me the following: Near Hana, on Maui, old natives say that there is found a limu, growing in two places, which is deadly poison. It is dried and powdered, put into a tube of *Pili*-grass and blown on to the person to be poisoned. Mr. Wilder Wight of Honolulu obtained from a Hawaiian sailor aboard the Steamer Kinau the following story: *Mualea* is the reputed poisonous limu of Hana, near Lahaina, on Maui. It is exposed at low tide, and it can only be handled with sticks. The locality is fenced off, and it even poisons fishes in its vicinity. Another story is to the effect that the locality where this poisonous limu is found is on the grounds of a villa which belonged to King Kalakaua, and that the King, in his lifetime, placed guards over the spot to prevent the limu from being gathered. All these stories seem to be from hear-say only. Some believe implicitly in the existence of this limu, while many believe it to be only a myth. I have written to a number of persons who might know definitely about it, but have failed to obtain answers.

NANEA. The family of the native clergyman at Puna have applied this name to a specimen of *Hypnea nidifica* J. Ag.

NANOO. *Limu nanoo* occurs in the list of Hawaiian names of limu given by Chamberlain. It may be another form of *Limu nano,* the dark red or purple seaweed.

NANUE. Andrews has *Limunanue,* and Chamberlain has *Limu nanue. Nanue* means a swelling.

NANUI. The Kawaihae Fishermen mentioned this as a limu growing at Kohala, and described it as edible and very much like *Lipoa.* Mohokini says that it is found on Maui, is six inches long, and grows in salt water.

NOHOMAHE. This is the name given to specimens of *Chaetomorpha antennina* (Bory) Kuetz. (as determined by Mr. Collins), by the family of the native clergyman at Puna.

OAOAKA. Chamberlain has *Limu oaoaka* in his List. *Oaoaka,* according to Andrews, means to glitter, to glisten, to spangle.

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OHIOHIO. This name is given by Chamberlain as *Limu ohiohio.* The derivation seems to be *o,* the intensive, and *hiohio,* bright red.

OKALA. A specimen collected and named *Okala* by the family of the native clergyman at Puna has been determined by Mr. Collins as *Galaxaura rugosa* (Solander) Lam'x. The derivation seems to be from *o,* the intensive, and *kala,* rough.

OKUPE. I have found this name only in the *Limu okupe* of Chamberlain's List.

OOHIEA. *Limu oohiea* in Chamberlain's List is the only information I have concerning this name.

OOLU. This seems to be a favorite about Honolulu, and I found it in the fish market, but in masses so soft and losing its red color that I could not determine it. John Poai applied the name to fairly well grown specimens of *Laurencia obtusa* var. *racemosa* Kuetz. Charlie Cook insisted that the name *Oolu* belonged to specimens of *Hypnea nidifica* J. Ag., but, for good reason, I place little faith in the accuracy of most of his determinations.

OPAI. Andrews gives *Limuopai,* and Chamberlain *Limu opai,* but I have not been able to trace the name further.

PAAKAI. Chamberlain lists *Limu paakai,* or salt limu. It is probably the same as *Lipaakai* as mentioned above.

PAAKAIEA. This name occurs both in Andrews and in Chamberlain as *Limupaakaiea* and *Limu paakaiea,* and is probably the same as *Pakaiea* mentioned below.

PAHAPAHA. Chamberlain gives *Limu pahapaha,* and John Poai says that it is the Kauai-name for *Pakaiea,* which latter he applies to a specimen of *Ulva fasciata* Delile. Miss Tilden, in her American Algæ (No. 464), distributes a specimen she determines as *Monostroma latissimum* (Kuetz.) Wittr., to which she appends the note: "The Hawaiian name is 'limu paha paha,'" and again, under No. 466, determined as *Ulva fasciata* Delile, she has the note: "The Hawaiian name for this alga is 'limu paha paha.' It is eaten with raw fish by the natives." Further remarks will be found below, under *Pakaiea.*

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PAHAPAHA O POLI HALE. This phrase, preceded by the word *Limu,* is found in Chamberlain's List. There must be some story connected with this, for *o* means of, *poli,* hollow, and *hale,* house.

PAHEE. Mohokini says that this is the Hawaii-name for the kind called *Lipahee* on Maui. The Kawaihae fishermen said that *Pahee* is eaten raw, and is put on when cooked meat is served. *Pahee* means smooth, polished, slippery.

PAKAIEA. This seems to be a well known seaweed, but the opinions as to its merit as an article of diet vary considerably. I met it first at Laupahoehoe, where I obtained a specimen of *Ulva fasciata* Delile, with this name, from a woman gathering limu. Other natives at Laupahoehoe confirmed the name, but all said that it was not "*kaukau,*" or edible. The Kawaihae fishermen told me that some people eat it, but it requires skill to prepare it. It is gathered, the long specimens being the most desirable, torn to pieces, placed in fresh water, then mixed with salt, and eaten with anything. A specimen of *Ulva fasciata* was labeled this by the family of the native clergyman at Puna, and John Poai also applied this name to specimens of *Ulva fasciata* at Honolulu. Poai also vouchsafed the information that on Kauai it was called *Limu pahapaha.* Both *Pakaiea* and *Limu pahapaha* are probably used for any form of Ulva or Monostroma, the essential meaning being broad, in the sense of membranous.

PAKAELEAWA. Mohokini gives this as the name used on Maui for the plant called by the Hawaiians *Huluhuluwaena,* and one of the Maui women on the steamer seemed very much amused when, in questioning Mohokini, I used the latter name. I was very careful to be certain of the spelling, questioning Mohokini several times about it, through Mr. Emerson as interpreter.

PAKELEAWAA. Chamberlain has *Limu pakeleawaa,* which however, may be another spelling for the preceding.

PALAHALAHA. Andrews has *Limupalahalaha,* and Chamberlain has *Limu palahalaha,* while Mohokini gives *Lipalahalaha.* The last mentioned says that *Lipalahalaha* is the Maui-name for *Pakaiea. Palahalaha* means, according to Andrews's Dictionary,

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(1) broad, and (2) a species of limu. John Poai applies this name to a seaweed which Mr. Collins refers doubtfully to *Laurencia perforata* Mont. I think, however, that the Hawaiian name refers more properly to species of Ulva and Monostroma, which are broad and membranous.

PALAPAHAKOU. John Poai gives this name to clumps of *Centroceras clavulatum* (Ag.) Mont. The name may come from *pala,* soft, *paha,* broad or extended, and *kou,* moist or wet, three adjectives which might very well apply to this alga when its clumps or masses are freshly gathered from the water.

PALAWAI. Andrews has both *Limulipalawai* and *Limupalawai,* while Chamberlain has both *Limu lipalawai* and *Limu palawai.* Mohokini uses *Lipalawai,* while Poai uses *Palawai.* I think that all refer to the same species, which must be some fresh-water Confervoid species. Poai says that *Palawai* is found in running fresh water, and looks like *Limu eleele,* but is not so coarse as that form. As mentioned above, *palawai* means running fresh water.

PALEWAWAE. This name is attached to a specimen collected and named by the family of the native clergyman at Puna. The plant is a young Laurencia, not determinable as to species. The derivation seems to be from *pale,* protection, and *wawae,* leg. This word means also greaves or leg-protectors, but what it refers to as the name of a limu is doubtful.

PAPAAKEA. Mr. Collins identifies as *Liagora valida* Harv., a specimen to which this name is applied by the family of the native clergyman at Puna. The derivation is from *papaa,* hard, and *kea,* white, a name well characterizing this species.

PEEPEE. Mohokini says that *Peepee* is the Maui-name for the plant called *Aalaula.* It lasts only one day. If Mohokini is right, it must be different from *Lipeepee.*

PEHU. Chamberlain gives *Limu pehu. Pehu* means swollen. Chamberlain also lists *Limi lipehu,* as noted above.

PEPEIAO. Chamberlain has *Limu pepeiao. Pepeiao* means ear. Poai applies the name to *Padina Pavonia* (L.) Lam'x., an excellent name for it. He also called the same species *Pilipiliko'a,* as mentioned below.

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PEPEULU. I find this name only in the *Limu pepeulu* of Chamberlain's List. *Pepe* means soft and *ulu* means wet.

PILIKO'A. A specimen, determined by Mr. Collins as *Galaxaura lapidescens* (Solander) Lam'x., is named this in the collection made by the family of the native clergyman at Puna, and John Poai referred a Galaxaura, probably of this species, also to *Piliko'a.* The name may have reference to the likeness between the Galaxaura and a coral.

PILIPILIKO'A. John Poai says that this name is often applied to the limu known as *Pepeiao,* because it grows on the branching coral. *Pilipili* means to stick to, and *ko'a* is the branching coral.

PIPILANI. I find this name only in the *Limupipilani* of Andrews and the *Limu pipilani* of Chamberlain.

POHA. Miss Tilden, under No. 436 of her American Algæ, which is *Hydroclathus cancellatus* Bory, states that "the Hawaiian name for this alga is 'poha.' It is eaten raw by the natives." *Poha* means to burst.

PUHA. John Poai gives this name for a specimen of *Colpomenia sinuosa* (Roth) Derb. et Sol. *Puha* means "to burst or break open, as a sore or a boil," according to the definition in Andrews's Dictionary. The word is well applied to Colpomenia.

PUPUKANEILIO. I find nothing further concerning this name beyond the *Limu pupukaneilio* of Chamberlain's List.

UAUALOLI. This is the *Limu uaualoli* of Chamberlain's List. The derivation seems to be from *uaua* and *loli,* the first meaning tough and the second a kind of holothurian, the biche de mer.

ULAULA. This name occurs both in Andrews and in Chamberlain, as *Limuulaula* and *Limu ulaula,* respectively. *Ulaula* means red, and is also the name of a red fish.

WAWAEIOLE. John Poai says that this name is sometimes applied to *Codium Muelleri* Kuetz., generally called *Aalaula.* The name comes from *wawae,* meaning foot, and *iole,* meaning rat.

WAWAHIWAA. This name is represented only in Chamberlain's List as *Limu wawahiwaa.*

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Vol. 2, No. 5, pp. 139-168, Pls. 15-17 July 25, 1905

REGENERATION AMONG KELPS

BY

WILLIAM ALBERT SETCHELL

BERKELEY

THE UNIVERSITY PRESS

PRICE $0.30

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CONTENTS.

		PAGE
I.	Introduction	139
II.	Continuous Physiological Regeneration in Laminaria Sinclairii	140
III.	Periodic Physiological Regeneration in Laminaria Sinclairii	141
IV.	Periodic Physiological Regeneration in Laminaria Andersonii	145
V.	Periodic Physiological Regeneration in other Laminariaceæ	146
VI.	Restorative Regeneration in Laminaria Sinclairii	146
VII.	Restorative Regeneration in other Laminariaceæ	149
VIII.	Summary and Discussion	150
IX.	List of Works referred to	161
X.	Explanation of Plates	164, 166, 168

Introduction.

The subject of regeneration among plants has been summarized by Morgan (1901) and by Goebel (1902). Since these papers, there have been many others dealing with this subject, and particularly on the side of the higher plants, including also mosses, ferns, and their allies. The fungi have received little attention, and while considerable work has been done on the algæ, it has been done chiefly in connection with cœnocytic forms, or with those forms which disintegrate under unfavorable conditions and some of whose cells, thus separated, continue to grow and show reactions of various kinds to their unwonted surroundings. Little attention has been paid to the regeneration of more complex forms of algæ, but Oltmanns (1889) and Küster (1899) have brought forward some very interesting facts and considerations in this connection and have referred to many incidental facts along these lines mentioned by previous

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writers. Oltmanns and Küster deal with the Fucaceae especially, but the latter investigates also many other complex algæ belonging to both the Phaeophyceæ and the Rhodophyceæ. Neither of them find any cases of regeneration (*i.e.*, proliferation) among the Laminariaceæ, in which the writer has found some most interesting cases.

Regeneration is, in the ordinary use of the term, so general a designation, as to include phenomena of such diverse kinds, that there must be several subdivisions recognized, in order that its full significance, as well as the significance of any particular type of phenomenon, may be discussed with clearness. So far as the present paper is concerned, the term is used in its widest sense, viz., the replacement of parts lost. This is the general sense adopted by Morgan. It seems best, also, to distinguish for the purposes of this paper, between physiological regeneration and restorative regeneration, using the terms in the same sense and with the same points of view, as indicated by Morgan.

In the Laminariaceæ, the several kinds of regeneration are often to be observed in one and the same species, but no species so far studied by the writer exhibits the phenomena so clearly as a Californian plant, *Laminaria Sinclairii* (Harvey) Farlow. The discussion of the regeneration in this species will be arranged under the three heads, *viz.*:—Continuous Physiological Regeneration, Periodic Physiological Regeneration, and Restorative Regeneration.

Continuous Physiological Regeneration in Laminaria Sinclairii.

Laminaria Sinclairii is a gregarious species, covering the rocks thickly in the wave-swept portion of the litoral zone on the coasts of middle and northern California. Its basal portion consists of creeping rhizomes which cling to the rocks by branching hapteres and which emit upright fronds in some abundance. In the possession of these rhizomes, it differs from most of the species of the genus and even from those of the same family. The upright fronds have three regions distinctly marked off from one another. There is a long, slender, slightly flattened

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stipe below, a long, narrow, expanded blade or lamina above, and between the two, an inconspicuous region which is meristematic, furnishing the increase in length to both stipe and blade. It is from this intercalary meristem or transition-place, that the continuous physiological regeneration of the blade proceeds. During the vegetative period, constant additions are made, both to the tip of the stipe and the base of the blade. The stipe, consequently, constantly increases in length. The blade, however, only reaches a certain, almost fixed, length, since the constant erosion at the tip, due to the powerful wave action, is simply made good by the increase in length from below. Such continuous physiological regeneration is characteristic of all species in the family of the Laminariaceæ and is continuous throughout the season of active vegetative growth. Towards the end of the season of active growth, this continuous renewal gradually ceases, until it finally comes to a stop when the plant passes into the stage of rest, either at the end of its life, as in the annual species, or for the winter season, as in the perennial species. The physiological regeneration is renewed at the beginning of the next growing season in the case of the perennial species, with increased activity for the time being, giving rise to the phenomena of the so-called "renewing of the blade," so conspicuous in many, especially in the digitate, species. The renewal of the blade presents several characteristic features and may be distinguished from the phenomena described above as Periodic Physiological Regeneration.

Periodic Physiological Regeneration in Laminaria Sinclairii.

The external appearance of any species of the Laminariaceæ during the period of the renewal of the blade or casting off the old blade, is certainly striking. The old blade, which is thick and often sorus-bearing, seems to be lifted from the tip of the stipe by the new blade, and as it wears away very rapidly and the new blade grows very rapidly, it seems to be literally "cast off." The line of demarcation between the two blades is very sharp in *Laminaria Sinclairii*, due not only to the dif-

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ference in color and consistency, but also to the constriction formed at the junction of the downwardly tapering base of the old blade and the upwardly tapering tip of the new blade. The process while well-marked in the species under discussion, is even more striking in some of the species of the digitate-group of the genus Laminaria, where the blades are much broader and are digitately divided.

The phenomenon of the renewal of the blade was noticed early, but no especial attention was paid to it until the classic papers of LeJolis (1855 and 1856). LeJolis found that there was a sufficient difference in detail in the process among the digitate species of Laminaria to serve a useful purpose in distinguishing between different species. Since that time several authors have mentioned and discussed the process, especially J. G. Agardh (1867), Areschoug (1884) and Foslie (1884). Since these papers, very little of an original nature has been published on this phenomenon.

The attention of the writer was first called to the renewal of the blade, while studying the Laminariaceæ of the coast of New England. The observations of Foslie on the digitate species were confirmed. In the case of species of Laminaria which are perennial and with undivided blade, it was found that something resembling renewal took place twice in the year, in the spring and in the autumn at the approach of winter (*cf.* Setchell, 1900). The study of these New England plants brought out little that was new, but an examination of some plants of *L. Sinclairii,* sent from Santa Cruz, California, by Dr. C. L. Anderson, showed that at the tip of the stipe there were present peculiar structures called by Dr. Anderson "collars." A search through the literature on this subject showed that Areschoug had noticed them, for he says in his description of *Hafgygia Sinclairii,* "Folium basi a trunco quasi vaginatum" (1883, p. 6). The writer (1896, p. 45) was the first to call attention to the relation existing between these structures and the process of the renewing the blade. The subject has since been studied further and the results are given below and in the series of drawings accompanying this article.

In the region of San Francisco, California, if one examines

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the old, and at this time well fruited, plants of *Laminaria Sinclairii,* about the middle of November or somewhat later, there will be noticed at the transition-place, a slight horizontal bulging. If one stretches the frond slightly in the longitudinal direction, the outer tissues at the transition-place will crack and rupture and show a small region of new tissue underneath. Soon after this stage there may be seen on the bulging area, in an uninjured growing plant, longitudinal, parallel cracks, and later a transverse rupture, sometimes extending regularly from one margin to the other, but sometimes only at one margin. The ruptured cortical tissues project upward from the stipe, forming the collar mentioned above, while from the base of the old blade, there projects a corresponding collar which is much less pronounced and which soon wears away. The portion of new blade laid bare by the rupture of the cortical tissues, rapidly increases in length, being set off very plainly not only by the constriction between it and the old blade, but also by its lighter color and softer texture. The details of the process, as seen with the naked eye, are well shown in the series of figures from 1 to 13. Figure 1 shows the condition just before any visible rupture takes place. As stated above, if a plant in this condition is stretched longitudinally or bent at the transition-place, the cortical tissues will split, thus showing that they are already separated from the tissues below them. If left undisturbed to take its normal course, the split will take place as shown in figures 2, 3, and 4. The rupture sometimes takes place simultaneously across the whole region, but more often, as shown in figures 3 and 4, it starts at one margin and proceeds more or less slowly to the other. The farther growth of the new blade is shown in figures 5, 6, and 7. The turning back of the cortical tissues occurs during these stages, forming the so-called collars. Figures 8 and 9 show details of farther growth of the new blade together with the fruiting relations of the old and new blades. The old blade always shows a well marked sorus, occupying the central portion of each surface, while the new blade shows a sorus only rarely and then only at the very tip. Both conditions are shown in the figures just quoted, the sori being indicated by the portions of the blades more heavily

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shaded. Figures 10, 11 and 12 show an oblique splitting, so that the old blade is pushed off at an angle more or less approximating to a right angle, but the position of the new blade is normal. Figure 13 shows a longitudinal split in the new blade and such forms probably give rise to plants in which the stipe is forked above. Such forked fronds are frequently found. They combine the periodic physiological regeneration with restorative regeneration which will be discussed later on.

A longitudinal section through a specimen of *Laminaria Sinclairii* in a stage of regeneration indicated in figure 2 is shown in figure 18. Only one longitudinal half of the section is shown, but there is clearly brought out the relation of the disrupted tissues to the rest. In the upper end is the tissue of the stipe and below, that of the blade. The separation occurs just within the outer cortex and in the tissues of the inner cortex. The exact position of the first separation is shown at the place (*a*) where the outermost layers of the new blade look as if they had been wounded. The matters of particular interest are two: the cells which initiate the rupture and the relation to the mucilage ducts. The cells which take part in the elongation are those of the medulla and inner cortex, the cells of the outer cortex and those of the limiting layer take no part. Consequently the rupture takes place at the region where the cells of the outer cortex pass over into those of the inner cortex. This may be seen readily in the figure which is half of a longitudinal section taken through the region of activity in a stage just succeeding the rupture. The outermost cells of the inner cortex in this region actively divide in planes perpendicular to the surface, forming a new limiting layer and outer cortex as they divide also parallel to the surface. The relation to the mucilage ducts seems to be that they do not divide along the plane of those ducts. At first, the writer suspected that the plane of division or rupture might be at the region where the mucilage ducts are situated, but this is not so. It appears that the rupture takes place in the region where there are no mucilage ducts, *i.e.*, the transition-place. In a plant which is active, *i.e.*, has continuous physiological regeneration, the mucilage ducts of the blade descend to the transition-place but do not pass into

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it. A similar condition exists in the stipe. Consequently, there is a region, the region of activity of growth in length, in which there are no mucilage ducts to be found. This is the region where the rupture of the cortical tissues takes place. The phenomenon, then, is one of localization of the power of renewing growth in the inner cells. It occurs also in the case of restorative regeneration, as will be shown below. The investigation of the histology of this process has not been followed out more particularly than to determine these two points.

Periodic Physiological Regeneration in Laminaria Andersonii.

A good opportunity was given, of studying the process of periodic physiological regeneration in *Laminaria Andersonii,* in January, 1899. A great many plants were observed at Pacific Grove, California, all showing stages of this process. The process differs only in detail from that as shown by *Laminaria Sinclairii.* The same rupture of the cortical tissues occurs and apparently in the same general region. The figures on plate 17, accompanying this article, show the stages observed better than they may be described. The very first stage is shown in figure 19, where the rupture is seen just starting in the middle of each surface at the very base of the blade. In figure 20, it has become somewhat larger, while in figure 21, it has reached the margin. This is shown slightly more advanced in figure 22. In figure 23, the rupture is complete all the way around and the new blade is fully started. In figure 24, we see the new blade in a somewhat more advanced condition and the constriction between the new and old blades is very manifest. Figure 25 shows a still later stage and in figure 26, we see a stage characteristic of the digitate Laminariæ with mucilage glands in the stipe, in that the new blade has begun to split while the old blade is still largely intact upon its summit. The collar at the tip of the stipe of a renewing plant of this species is almost as large and conspicuous as it is in *L. Sinclairii.* Besides the series seen at this time and locality, the writer has seen other plants of *Laminaria Andersonii* showing renewal and they all agree with those seen at Pacific Grove in early January, 1899.

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Periodic Physiological Regeneration in other Laminariaceæ.

It certainly seems that there is good reason for believing that the rupture of cortical tissues found in connection with the renewal of the blade in the two species of Laminaria described above, is general for all species in which this phenomenon is found. The writer has observed it in two other cases, *viz.*, in *Laminaria Farlowii* and in *L. platymeris*, as mentioned by him in a preceding paper (1896, p. 46). *Laminaria Farlowii* is a species of the Simplices-group, growing in some abundance in certain localities on the coast of Central and Southern California. The writer has collected a number of specimens at various times, in the condition of renewing and has noted a very distinct collar at the tip of the stipe (*cf.* Fig. 17, *b*), but not so pronounced as that occurring in *Laminaria Sinclairii*. *Laminaria platymeris* is a species of the digitate-group with mucilage ducts and showing a very pronounced renewal. In one specimen in the writer's collection, there is a fairly distinct collar at the tip of the stipe of a specimen from northern New England. The general occurrence of the rupture of the cortical tissues at the time of the renewing of the blade seems, therefore, likely to be found to exist. *Laminaria Sinclairii, L. platymeris* and *L. Andersonii* have mucilage ducts in the stipe, but *L. Farlowii* has not.

While the renewal of the blade is most striking and best known in species of the genus Laminaria, it has been seen also in species of other genera of the Laminariaceæ. J. G. Agardh (1867, p. 1) has described it in Agarum. Ruprecht has mentioned it as being frequently seen in *Lessonia laminariaeoides* P. & R. Areschoug (1884, p. 16) states that renewal of the blade takes place even in *Alaria esculenta* (Lyngb.) Grev. Data for comparison of the details of the process in these other genera and those of the renewal in Laminaria are unfortunately wanting, so that it must remain in doubt whether the resemblance is only superficial or whether there may be a rupture of cortical tissues or not.

Restorative Regeneration in Laminaria Sinclairii.

While studying the renewal of the blade in *Laminaria Sinclairii*, the writer found many plants curiously branched and

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careful search showed that the branches originated by a process of restorative regeneration. In every case, where the origin was at all certain, it was found that the branches originated from wounded surfaces. Various methods of branching, which were found were seen to have their origin according to the direction of the wound relatively to the direction of growth of the stipe. It is possible to distinguish three different directions, *viz.*, horizontal, vertical, and oblique.

The horizontal wounds occur transversely on the stipe and are very common, *i.e.*, comparatively. They are most readily recognized in the earlier stages. The whipping back and forth of the fronds by the heavy waves rolling in over the rocks inhabited by the plants of this species, snaps off the tips of the blades and occasionally, even all of the blade down to the transition-place, or even below it. The horizontal wounded surface of the stipe, however, puts forth another blade and the process soon appears like the normal growth, since there is here, no branching in the ordinary sense of the term. Figure 14 shows such a process of regeneration at the tip of the specimen.

Vertical wounds, longitudinal to the stipe, may be inflicted either at the tip or on the sides of the stipe. When the vertical wound is at the tip, it usually results from the splitting of the blade and the extension of the split down into the region of the transition-place. The exposed surfaces heal and become rounded below, the meristematic region at the transition-place now represents two regions of activity for growth in length and a bifurcation of the stipe results from farther growth, so that the resulting branching is a forking. Such a case of regeneration is well shown in figure 15. An earlier stage is shown in figure 13. Such bifurcate specimens are far from uncommon. If, on the other hand, the vertical wound is situated on the sides of the stipe, instead of healing and forming scars, the tissues exposed grow out into blades as shown in the lower case of regeneration in figure 14. The blade, in such a case, comes to possess a transition-place and at this a portion of stipe is formed, as may be seen in the middle case of restorative regeneration in figure 14, and the result is a horizontal branch. Several horizontal branches are represented in figure 16. Few or many

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horizontal branches often occur on plants found growing or cast ashore.

Oblique wounds are not quite so common as the previously mentioned ones, but do occur with some frequency. The results are very similar to those from vertical wounds. The difference is in the angles which the branches form with the stipe. In the former case, the angle is a right angle, but in the latter case, the upper angle may be either acute or obtuse. If the oblique wound is at the tip of the stipe, then the continuation of the stipe by the resulting regeneration is at an angle with the rest of the stipe. Cases are met with in which after one regeneration from an oblique wound, a second oblique wound has been inflicted, higher up, and a second angle formed, and where this has been repeated several times, the stipe assumes somewhat of a zig-zag course. When the oblique wounds are made on the sides of the stipe, they give rise to branches projecting at different angles from the stipe.

An investigation of the histology of the processes of restorative regeneration in *Laminaria Sinclairii* shows that the tissues concerned in producing the new blades, stipes and transition-places, are very similar to those concerned in the renewal of the blade in periodic physiological regeneration. It is only the inner tissues which take part in this process. The inner cortex and medulla grow forth, while the outer cortex and the limiting layer take no part in the regeneration. The new blade arising from a wound appears as a small papilla in the center of the wound, if it happens to be transverse to the stipe, or as a narrow ridge of tissue, if it happens to be an elongated vertical wound, no well marked callus preceding the growth. The outer tissues of the region of a wound simply harden, but do not grow at all.

From what observation has been possible in the case of *Laminaria Sinclairii,* it seems that the possibilities of restorative regeneration, are limited to the earlier part of the season, *i.e.,* to the time of the first starting of the frond to grow and to the period of the renewal activity. No fronds have been found in the early stages of restorative regeneration except at the periods noted. No experiments, however, have been tried, to determine this point with accuracy.

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Restorative Regeneration in other Laminariaceæ.

Restorative regeneration is by no means limited to *Laminaria Sinclairii,* but this is the only species in which the writer has been able to follow the process in its general details. Other members of the group of the Laminariaceæ show modifications which are to be attributed to this process. We find, for instance, that bifurcate forms of several species and genera have been observed and noted in the literature. A distinctly bifurcate form of *Laminaria digitata* is preserved in Herb. Farlow. Bifurcate forms of *Laminaria Andersonii* have occurred to Dr. C. L. Anderson and to the writer, on the coast of California. On the Northwest Coast of North America, bifurcate forms of *Laminaria Bongardiana* are fairly common and have been mentioned as a variety or form of that species by several writers. *Nereocystis Luetkeana* shows at times two complete or partial bulbs and such a specimen is figured by Saunders (1901, pl. 59, f. 9). A similar condition of *Pelagophycus giganteus* has been found at San Diego, California, by Miss Minnie Reed and is preserved in the Herbarium of the University of California. A specimen of *Postelsia palmaeformis* was found by Mrs. J. M. Weeks near Pacific Grove, California, which has two bunches of leaves on the side of the hollow trunk, about half way between the holdfast and the terminal bunch. Specimens of *Eisenia arborea* and *E. bicyclis* have been found with the arms forked the second time. Yendo (1902, p. 204), from the frequency of the occurrence of the second branching in *E. bicyclis,* is inclined to think that it is normal to the species and characteristic of the older plants. This view certainly needs stronger evidence for its support than any he advances at present. F. S. Collins has found on the coast of New England, two specimens of *Alaria esculenta* with bifurcate blades and rachises. In one case, however, the inner edge of each arm of the rachis is bare of sporophylls and shows no regeneration of sporophylls, while another specimen (collected at Nahant, Mass., May 30, 1899) forms sporophylls not only on the outer margins of the two rachises, but on the inner margins of both as well, thus showing "restitution" in the most perfect degree. A specimen of

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Pterygophora Californica was collected by the writer at Duxbury Reef, near San Francisco, California, which has the rachis bifurcate, each arm being 25-30 cm. long. Each of the secondary rachises, however, just as in the case of the Alaria just mentioned, has sporophylls on both margins.

Occasionally, the writer has found adventitious hapteres coming from the stipe of species of Laminaria which may or may not be the result of injury and, consequently come under the head of regeneration. One case, in particular, happened in connection with plants of *Laminaria longicruris*, growing on the piles of a wharf at Mystic Island, Conn., the bunch of hapteres was situated midway between the holdfast and the blade, and may have been stimulated by the abrasion caused by the rubbing of the stipe against mussel shells growing abundantly just above the Laminaria.

With the bifurcate forms may possibly be associated the trilaminate forms often seen in *Laminaria saccharina, Agarum Turneri,* etc., where there is a "third blade," or wing, at right angles to the normal blade and attached to it along one edge, although no chance has been given to study the origin of such structures as yet. If they are cases of restorative regeneration, they will differ from all others at present known among the Laminariaceæ, by the fact that the regeneration-structure is confined to the blade. In all the cases noted above, the regeneration proceeds only from the stipe.

Summary and Discussion.

The observations and figures accompanying them on the regeneration-processes of the Kelps are entirely the result of observation. It has not been convenient to do any experimenting as yet along any of the several lines of query which naturally present themselves in connection with the subject. It is hoped that attention will be drawn to this line of work and to the details brought out, that we may obtain a more exact knowledge of the various processes of regeneration as shown in this group and that experimentation may carry us farther than mere observation has done. The limits of divisibility of the stipe of *Laminaria Sinclairii* without losing the ability to

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regenerate is one problem which must remain open until experimentation may be engaged in. So far as the writer has seen, it is very probable that, even were a stipe cut off very near the base, it would still regenerate from the tip of the remaining stump. One stipe has been found regenerating, which was only 3 cm. long, but, of course, there was nothing left to show how long the stipe was before being mutilated. Some stipes, however, grow to be 20—25 cm. in length. The question as to the polarization of the stipe of *Laminaria Sinclairii,* as indicated by regeneration phenomena is one which cannot be settled with the present data. One specimen was found floating by Dr. C. L. Anderson, in which there appeared to be a blade at each end, thus giving an impression that heteromorphosis might be possible, but the evidence is simply suggestive and not final.

The relation between the existence of these several kinds of regeneration in *Laminaria Sinclairii* and liability to injury is certainly close. The specimens grow upon rocks washed, at high water, by heavy waves. The fronds are whipped back and forth with very considerable vigor. The tips of the fronds are very certain to be broken and worn away, unless provided with some means whereby this may be prevented. Such means do not exist in the species under discussion or in any of the kelps, all of which are ordinarily, although usually in less degree, liable to the same sorts of injuries. This seems likely to have been the influencing factor in bringing about the situation of the meristem for growth in length at the transition-place instead of at the tip where it exists in most algæ. There is nothing to be contributed to the discussion of the problem as to whether the power of restorative regeneration, or regeneration in the narrower sense, has been brought about in this species by natural selection or not. The percentage of individuals showing restorative regeneration has not been determined with any accuracy, but is sufficiently large to enable one to obtain a considerable number of specimens from any fair-sized group of fronds.

One of the first facts learned from the study of the processes of regeneration in the Laminariaceæ, especially as illustrated by such a species as *Laminaria Sinclairii,* is the association of the three methods of regeneration (as taken in the

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broadest possible sense), in the same individual. It can, and often does, exhibit the three kinds in the course of life of the same individual. Ordinarily it shows both continuous physiological regeneration and periodic physiological regeneration, and under the proper circumstances, it may also show restorative regeneration. Furthermore, there is a close similarity between these three kinds of regeneration which has made it desirable to include them all under the same general designation as has been done in this paper. The same organ and the same general region is the seat of each one of these three methods. In continuous physiological regeneration and in periodic physiological regeneration, the region concerned is the tip of the stipe or, at least, the region where the stipe passes over into the blade. In restorative regeneration, it is the same region, exactly, in the case of regeneration after a vertical splitting, and is some portion of the stipe even in restorative regeneration. The writer has never seen a case of restorative regeneration originating in the blade.

A second matter of importance brought out by the facts of regeneration detailed above, is that in the case of periodic physiological regeneration, the outer tissues take no part. They behave as if they were dead, yet there is no pronounced appearance of either death or disintegration. Even in the sections made at the earliest rupture, they are still possessed of all the characteristics of living cells. This matter is of some importance, as it seems to the writer, in view of the statement made above that all three kinds of regeneration are simply variations of one process. The considerations leading further along this line of reasoning may be given better below in connection with others.

Another thing which it may be well to emphasize in connection with periodic physiological regeneration in the Laminariaceæ, is the passing into a state of rest of the whole plant at the time of fruiting. This is to be seen even in the case of the annual species where it is a sort of ripening process. The writer has already (1891, pp. 187, 188, and 208) shown how very different this adult fruiting stage is from the purely vegetative stage in *Saccorhiza dermatodea,* an annual species. Other

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species of this group, particularly of Laminaria, show similar contrasts between the earlier vegetative stages and the fruiting ones. The latter show thicker, darker colored fronds, and the fact that active growth has stopped, is shown by the ceasing of increase of length for the stipe and the actual shortening of the blade, since the erosion at the summit is no longer made good by an increase from below. In some individuals, the blade is worn down almost to the transition-place. There is evidently a period when all active growth and the processes of nutrition connected with it, are stopped. It is to be compared with the winter resting period of perennial and biennial flowering plants. The awakening of a perennial species when the growing season begins again is what results in the renewing of the blade and the consequent rupture of the cortical tissues at the transition-place connected with the production of the vegetative stages of a new blade and the season's increment to the stipe. The cortical tissues of the outer layers are no longer able to take part in growth, hence they are cast aside for reasons which the writer hopes to make plain below. The point to be emphasized here is this:—that there is a periodicity in the seasonal growth of the perennial Laminariaceæ similar to that of the perennial flowering plant, of extratropical regions at least.

We find emphasized in the case of restorative regeneration, a fact which has already come to light in connection with periodic physiological regeneration, and that is that it is only the inner tissues, those of the inner cortex and medulla, which take part in the new growth. This is certainly and strikingly true of the periodic physiological regeneration and of restorative regeneration after wounds which are horizontal or vertical tangential to the stipe. In the case of vertical splitting, it is less certain, but in this case, it is the meristematic tissue of the transition-place which is concerned, so that the exception, if it occurs, may perhaps be explained. In fact this exception is to be expected, although from the material at hand, it cannot be proven one way or the other, from the behavior of the tissues at the transition-place during the process of continuous physiological regeneration. The inner tissues are the ones concerned also in restorative regeneration in the Fucaceæ, as may be seen from what Oltmanns (1889, p. 74 *et seq.*) has described.

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In restorative regeneration, when the wounds are horizontal, the regeneration is strictly restitution. A new blade grows out from the inner tissues which has a characteristic meristem at its base, whence the remains of the stipe are increased in length at the summit and the new blade is increased in length at its base. In every way the part produced resembles and replaces the part lost. This is to be contrasted with Fucus and Pelvetia, in which, as we learn from Oltmans (1889, p. 74 *et seq.*), a cluster of branches is produced, while in *Laminaria Sinclairii*, at least, only one blade and stipe, of absolutely normal appearance, is produced. Judging from Küster's figure of *Gelidium capillaceum* (1899, p. 152, f. 5), proliferating from horizontal wounds, the details of origin and exact restitution must be the same as in *Laminaria Sinclairii.* The proliferations certainly seem to come from the inner tissues and there is only one from each transverse wound. A similar thing is true of the Marchantia-group as described by Vöchting (1885). On plate 12 of his paper he figures the regeneration of plants of *Marchantia polymorpha* and *Lunularia vulgaris* which show restorative processes which closely follow those found by the writer in *Laminaria Sinclairii.* In the majority of cases, Vöchting found that only one shoot arose from the transverse (or horizontal) cut. In some cases where two arose, one may suspect the presence of a secondary rib, since the new shoots arise from tissues, hardly separated as yet, morphologically from the midrib. In figure 14 of plate XII, is such a figure and in figure 15 of the same plate, there is represented a case of vertical median splitting, in which the resulting shoots regenerated, may be compared with the regeneration of *Laminaria Sinclairii* after a vertical split through the transition place and found to be almost identical in detail. The origin of the new shoots in the Marchantiaceæ, also, points to a close similarity with the origin of the new tissues in the processes of restorative regeneration in *Laminaria Sinclairii,* at least as regards the function of the tissues concerned in each case.

The most important fact brought out by these observations on the regeneration of *Laminaria Sinclairii,* is that in both the periodic physiological regeneration and in restorative regenera-

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tion, it is only the inner tissues which are active and concerned in producing the new growth. The outer tissues behave as if they had lost the power of farther growth. In the periodic physiological regeneration, the outer tissues are ruptured, yet they still have all the appearance of life and vigor. One of the first things which suggests itself, in this connection, is that the new growth may come from embryonal or meristematic tissue. But the tissues of the inner cortex do not seem to have this character or the power of dividing any more than, or in fact, judging from structure and behavior, as much as, the cells of the outer cortex and limiting layer. This is certainly the case in restorative regeneration also, where especially when it occurs at some distance below the transition place, the cells of the inner cortex have increased in volume and have decreased in proportion of protoplasmic content. It seems rather to be a function of position that the cells of the inner cortex situated at the wounded surface should be the first to initiate and carry on the new growth or to be so stimulated to action through the renewal of activity on the part of the plant as to proceed independently of the outer tissues and even to be compelled to rupture the latter, in the case of periodic physiological regeneration.

By the function of position, the writer has in mind the fact that the cells of the medulla, particularly the trumpet hyphæ or sieve hyphæ, are the conducting cells and their function of conduction is shared by the inner cells of the inner cortex. Through these cells the transfer of nutritive materials proceeds longitudinally and delivery is made to the cells of the outer cortex at different points along the medulla and inner cortex. It certainly seems reasonable to believe what seems to be so evident in the cases under consideration that the cells of the inner tissues at the place where activity of growth is stimulated, must necessarily have the advantage and even be able to shut out the outer tissues from any participation in the supply. The direct flow is easy to control while the small side streams may readily be largely diverted or stopped altogether.

In the case of periodic physiological regeneration, the renewal of activity in the spring, which results in the phenomenon of

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the renewal of the blade, is evidently the result of the stimulus received from the return of favorable conditions of environment, as well as, perhaps, some internal stimuli connected with the seasonal periodicity. At any rate, the meristem at the transition-place, starts again into activity and begins to make demands upon the conducting system for the materials stored in the lower portion of the stipe and in the hapteres. Being favorably situated, after the fashion of a strong terminal bud, the inner cells of the meristem absorb all the materials brought up from below and are able to shut out the cells of the outer tissues from any appreciable participation in the supply. As a result, the cells of the inner cortex and medulla are enabled to grow, to divide, and to produce a new blade, while the cells of the outer cortex are not. There seems to be no other adequate reason for this localization of the regenerating power in the cells of the inner cortex and medulla, to be brought forward. The suggestion is all the more plausible, since exactly the same thing happens, as the result of an entirely different stimulus in the case of horizontal and vertical tangential restorative regeneration.

As has just been noted, the inner cortical and medullary cells are the only ones concerned in the new growth in the case of restorative regeneration, especially after horizontal and vertical tangential wounds. The cases of restorative regeneration where the wounds are oblique, are considered for the purposes of this discussion, to be closely related to one or the other of the two cases just mentioned, *viz*:—either horizontal or vertical tangential. The stimulus in all cases of restorative regeneration among the Laminariaceæ, is most certainly largely and most actively from the outside. The exposure of cells which have always been enclosed within other tissues, suddenly to the external conditions of environment, and their severence from some of the cells with which they have been closely associated in position and activities, must bring the cells thus exposed into such change of environment, or stimulus, as to have far reaching effects. The changed osmotic conditions resulting are, probably, the ones most active in stimulating the renewed activity and the growth connected with the regeneration process. The change

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in osmotic relations may be, and probably is, greater in the case of the inner larger cells, but while this may stimulate these cells to grow, to a greater degree than the outer cells are stimulated, yet it seems that the monopoly of growth must be due here to the direct connection of these cells with the tissues which transport the nutritive materials lengthwise through the plant. This only, as it seems to the writer, can fully explain why the inner cells grow out into new structures and the outer cells remain almost or entirely quiescent.

Such an interpretation is to be applied to the facts made evident in the restorative regeneration in Fucus and Pelvetia as given by Oltmanns (*loc. cit.*) and is in agreement with the opinion of Küster (*loc. cit.*), who calls particular attention to the fact (*loc. cit.*, pp. 154, 155) that regeneration from the midrib is the rule in Fucus and also that the midrib contains the conducting tissues of the plant. The midrib is also the source of regeneration in Marchantia and Lunularia, as Vöchting (*loc. cit.*) has demonstrated, and as Küster very properly points out, even in flowering plants, such as Begonia, an injury to a "nerve" of a leaf, *i.e.*, to the conducting system, brings about processes of regeneration. An examination of other cases of regeneration in leaves of flowering plants, especially of some more recently brought forward, shows further examples of this. The developing of shoots at other portions of leaves than in immediate connection with the nerve or conducting tissues, as for example in the severed, or even in the unsevered, leaves of certain aquatic species of Utricularia (*cf.* Goebel, 1904) is quite a different matter, belonging to the stimulus of buds or other residual masses of embryonic tissue, and does not conflict with the explanation of the phenomena just discussed.

What seems to be a well-marked case of the influence of the flow being more easily induced in the vertical or longitudinal direction, by the pull of the tissues developing at the tip, as contrasted with those at the sides, is to be seen in the various cases of restorative regeneration among the Laminariaceæ, resulting from vertical splitting. In these cases, the tissues at the transition place monopolize the growth and, consequently, must control the flow of nutritive materials, while those at the sides make no

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growth and seem to exert no influence on the flow. A striking case of the same thing appears in plate XII, f. 15 of Vöchting's paper (loc. cit.) where a piece of the thallus of *Lunularia vulgaris* has been cut across horizontally and then split vertically from this first cut, down along the midrib. The regeneration has taken place from the horizontal surface of each longitudinal half only, none being evidenced along either longitudinal cut surface. The result is identical with what happens in *Laminaria Sinclairii, L. digitata, Alaria esculenta, Pterygophora, etc.,* in vertical splitting. The pull in the longitudinal direction is also shown in *Anadyomene stellata,* as figured by Küster (loc. cit., p. 144, f. 1). In this species, which is very simple as compared with the forms which have been discussed above, it is only the long radiating cells which come into contact with and can draw from, the short cells, which regenerate on cutting. These long radiating cells answer to the longitudinal axes and nerves of the higher plants treated of above.

The suggestions above agree with the trend of the results of the recent experiments of Loeb (1904) on Tubularians. He found that the factor concerned was the flow of materials and that by distributing the flow, *e.g.,* by cutting, or even by constriction, the process of regeneration might be controlled, at least, within certain limits. From Loeb's experiments and also from the observations recorded in this paper, it seems that the materials conducted need only be the nutritive materials. It does not seem necessary to assume the existence of a special organ-forming "Stoff" to account for the new growth and its particular nature. The elaborated materials stored in the lower portion of the Laminaria plant are those most readily available. The control of the direction of flow seems to be the important thing. In the periodic physiological regeneration and in the restorative regeneration in *Laminaria Sinclairii,* as probably also in the regeneration in Fucus, Pelvetia, and Marchantia, the inner cells of the cortex or of the midrib are able to monopolize the flow and completely to control it, since the flow is more ready in the longitudinal direction and any pull in that direction is more effective than it would be, were the longitudinal flow less ready. In the case of buds on woody stems of flowering plants, the varying

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strength of the buds and the freedom of flow are well known. In a species with strong terminal buds, this easiness of flow in the longitudinal direction and the consequent ability of the topmost bud to obtain the lion's share of the materials conducted, is manifest by the strength of this bud as compared with the lateral buds and by its predominance in the farther growth. Let the terminal bud be removed from such a stem or branch, and the stream may be diverted from its absolutely longitudinal course and the lateral buds develop. Usually, however, the lateral buds developing under such circumstances, are those nearest the top. Here again, the matter of the easier compelling of the stream of materials is made manifest, both as regards the power of the buds, as compared with those below them, and also by their ability to monopolize, in their turn, the materials conducted. Such is the case of the Willow, as Morgan (1904) points out, while in other cases, *e.g.*, *Arctium Lappa* (or Burdock), as he also points out, the buds toward the base are the stronger and develop more quickly (or solely) when the branch is separated and exposed to moisture, no matter whether they are placed in such a position as to be nearer or farther away from the earth's surface. This stronger condition of the basal buds in such plants is probably due to the same reason as the stronger condition of the terminal or upper buds in the former case. It is due to the ability to monopolize the materials from a conductive tissue in which the flow in length was impeded rather than facilitated and consequently could be easily diverted, in large part, laterally. The differences between the two cases of situation of the strong buds on branches, has been long known to morphologists and was well expressed by Asa Gray (1879, p. 49) in his division of woody plants into those with definite annual growth of branches and those with indefinite growth of branches. Gray's explanations of the reason for the relatively greater strength of the terminal buds in the first case and the relative weakness in the second, is along the same lines as those given by the writer. The writer fully agrees with Morgan (loc. cit., p. 229) that the farther development of the buds in each case depends on their relative strength.

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The writer agrees with Morgan that we cannot discuss the influence of polarity in such cases as yet and the cases of regeneration given in this paper seem further in agreement with the final remarks of Morgan (1904, p. 230) in that the peculiarities of the regenerative processes seem here at least, to be purely a matter connected with the flow of nutritive materials and that the matter of the determining of the direction, etc., of the flow is a purely physical problem. As to whether this will also apply to the cases, as in Salix, where, although it is easy to see why the upper buds develop before the lower, or even are the only ones to develop, the explanation of why the roots appear only on the basal portions, must be left to farther investigation. It may not be out of place, perhaps, to call attention to the difference of materials required by the two processes. The buds are all formed and need little else besides the crude materials (water and the like) for their development. The roots, on the other hand, must be formed from undifferentiated tissue and, consequently, make a heavy drain upon the elaborated materials. It is not unlikely that the physical differences between the xylem and phloem, as regards the control of the direction of flow, or the relative strength of the one or the other set of forming or developing organs, may furnish the desired explanation, and so resolve the problem of polarity into simpler terms.

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Explanation of Plates.

PLATE 15.

Laminaria Sinclairii (Harvey) Farlow.

1. Median portion of the frond of an adult plant just before the beginning of the process of the renewal of the blade.
2. A similar plant, showing the beginning of the rupture of the cortical tissues at the transition place.
3. A similar plant showing the process of the rupture of the cortical tissues somewhat farther advanced and more advanced on one margin than on the other.
4. A somewhat larger plant, of nearly the same stage as the last.
5. A plant similar to the first three, showing the rupture of cortical tissues complete and the formation of the two collars, one on the stipe and one on the blade, with the new blade showing between them.
6. Stage somewhat more advanced than the last.
7. Stage showing the new blade beginning to assume shape and showing still the two collars as well as the constriction between the old and the new blades.
8. Stage decidedly older than the last and showing the same things only to a greater degree.
9. Somewhat older stage than the last, showing the sori (more deeply shaded portions) on both old and new blades.
10. Portion of the middle of an adult plant, showing the process of rupture taking place obliquely.
11. Somewhat more advanced stage than the last.

All the figures were drawn by A. A. Lawson under the direction of W. A. Setchell, and are represented of natural size.

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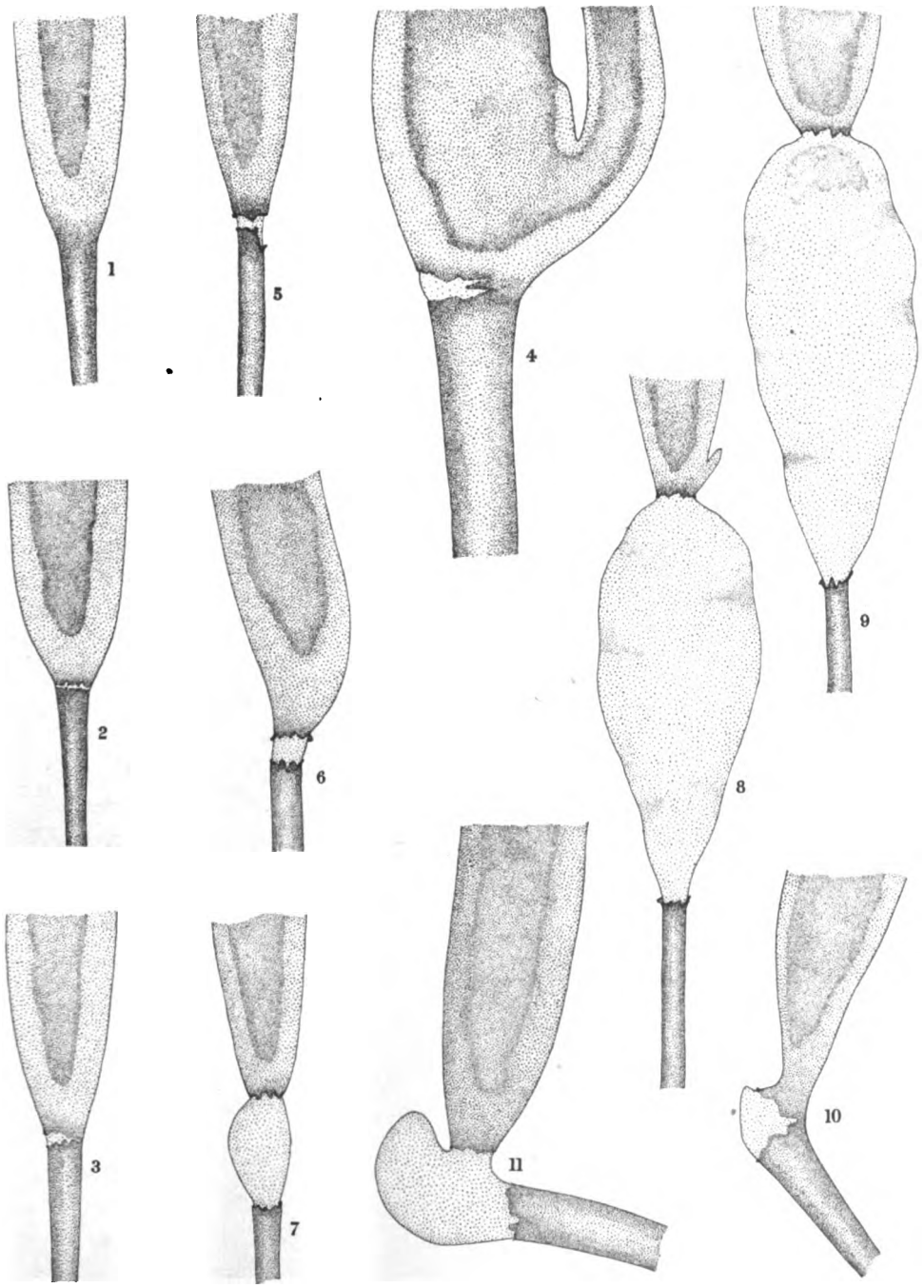

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PLATE 16.

Laminaria Sinclairii (Harvey) Farlow.

12. Portion of a plant showing a lower collar formed in a previous regeneration, and above a collar of the regeneration now taking place obliquely, of somewhat later stage than figure 11.

13. Portion of a large plant, showing regeneration and longitudinal splitting taking place in the young portion.

14. Portion of a specimen showing restorative regeneration, from a horizontal wound at the top, and from two vertical and tangential wounds below.

15. Figure of the upper portion of a bifurcate plant, evidently the result of restorative regeneration from a vertical wound through the transition place, showing periodic physiological regeneration (renewing the blade) on each tip. At *a* is the base of a branch probably from restorative regeneration from a vertical tangential wound.

16. Portion of the upper part of a plant, showing many branches, the results of processes of restorative regeneration.

Laminaria Farlowii Setchell.

17. A small plant, showing periodic physiological regeneration well advanced. The lower collar is fairly distinct (at *b*), while the upper collar (at *a*) is barely noticeable.

Figures 15 and 16 were drawn by H. N. Bagley and the others by A. A. Lawson, all under the direction of W. A. Setchell. Figure 17 is represented one quarter the natural size, the rest of natural size.

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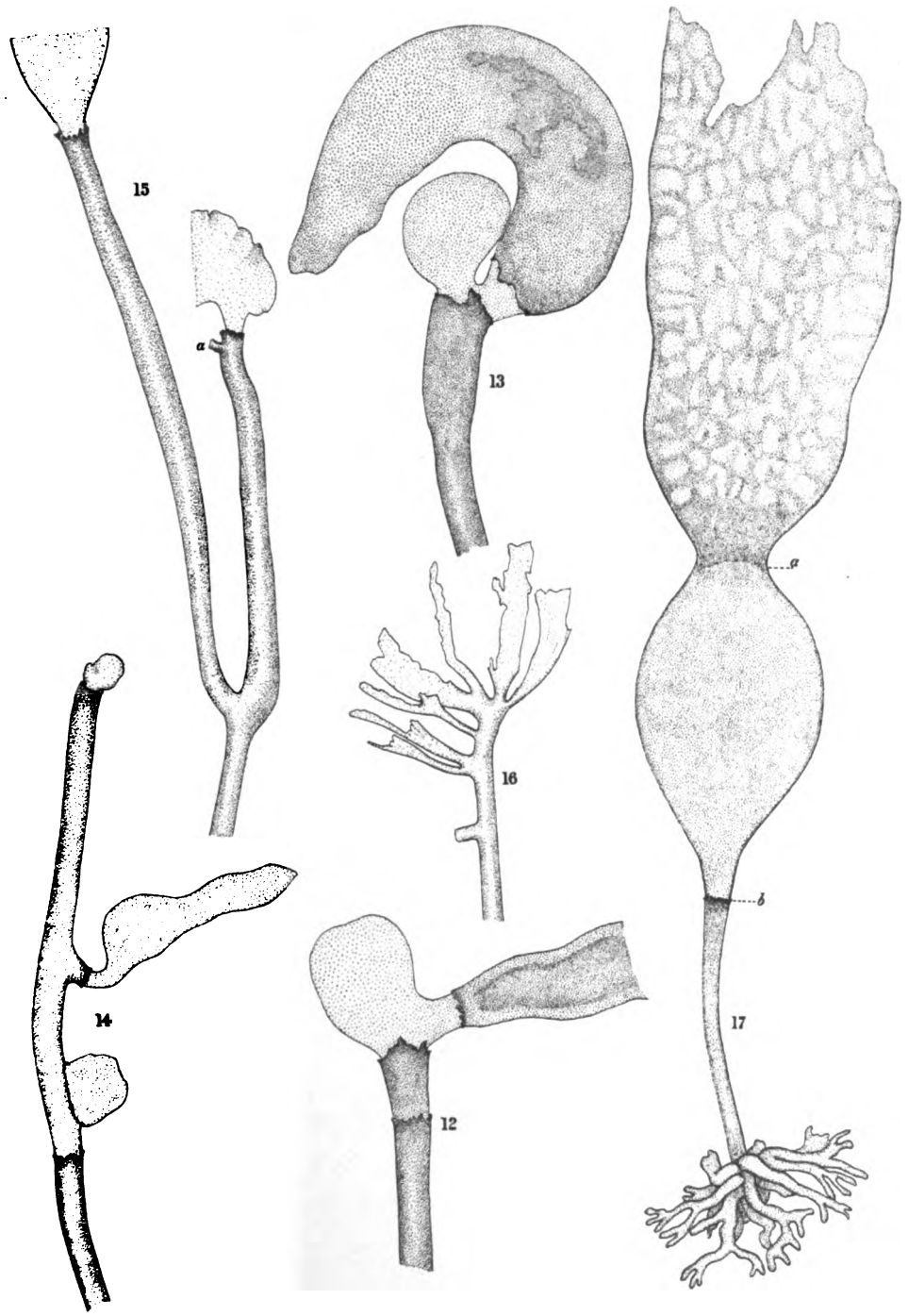

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PLATE 17.

Laminaria Sinclairii (Harvey) Farlow.

18. One half of a longitudinal section through the center of transition-place and adjacent regions of a plant in the early stages of the renewing the blade. The region of the stipe is toward the upper margin of the plate and that of the blade toward the lower margin. The projecting tissues on the upper and lower right-hand margins of the figure are sections through the two collars and at *a*, is the region where the rupture first took place.

Laminaria Andersonii Farlow.

19. Median portion of an adult frond, showing the beginning of the rupture of the cortical tissues at the beginning of the renewal of the blade.

20. Somewhat more advanced stage of the same.

21. Portion of a plant, showing the rupture of the cortical tissues extending to one margin.

22. Somewhat more advanced stage of the same.

23. Portion of a plant, showing the rupture of the cortical tissues complete and the new blade already well started. The collars are to be noticed, although they are not quite so prominent as in *L. Sinclairii.*

24. Somewhat more advanced stage of the same, showing the collars more distinctly, the constriction between the new and the old blades, but the latter as yet entire.

25. Very advanced stage in the renewal of the blade, showing the old blade just about to be cast off entirely, while the new blade has reached a fair size and adult shape, and has even begun to split. The lower collar is quite distinct at this stage.

Figure 18 was drawn by H. N. Bagley, the rest by A. A. Lawson, all under the direction of W. A. Setchell. With the exception of figure 18, which is highly magnified, all the figures are one quarter the natural size.

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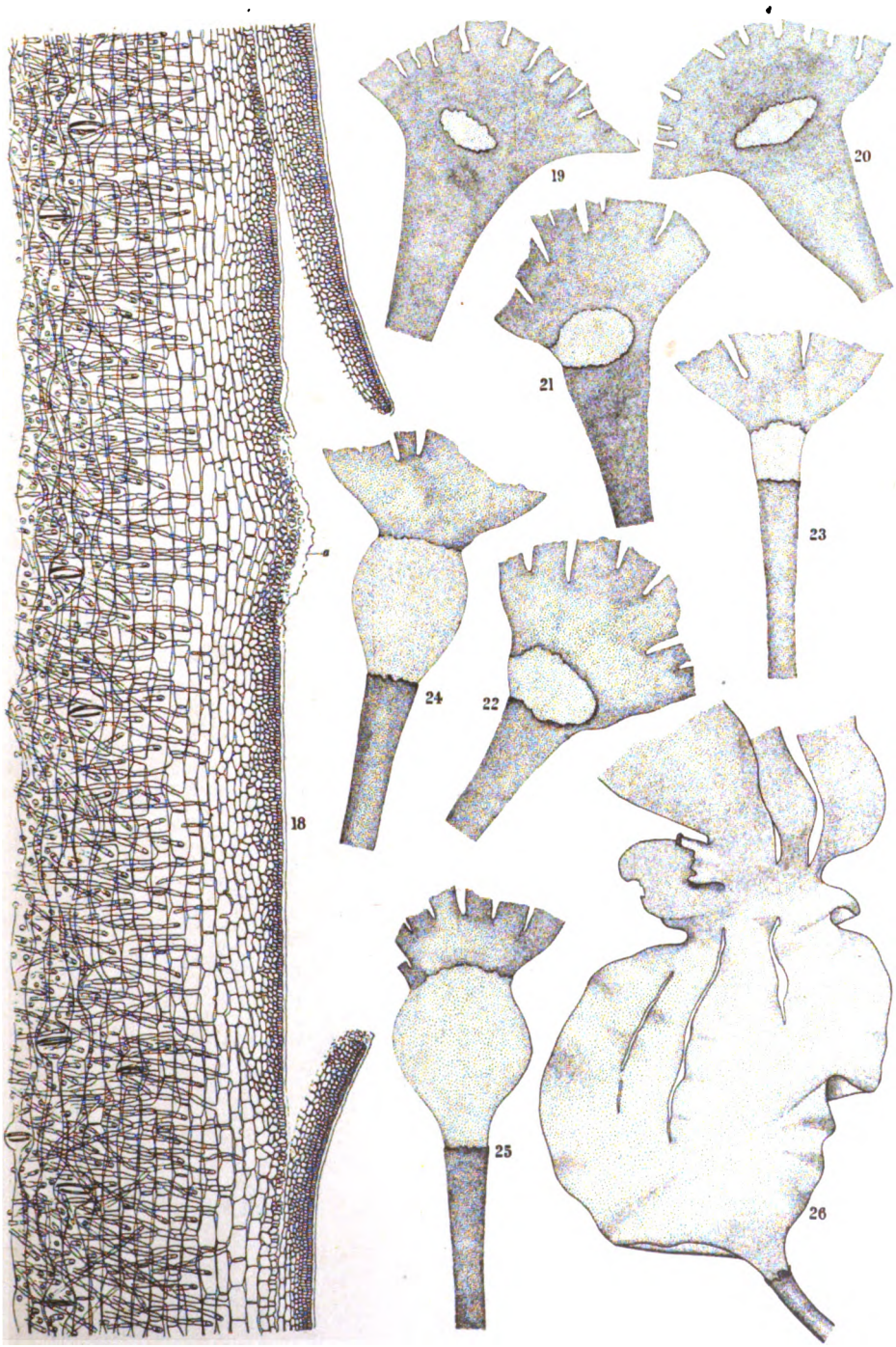

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

BOTANY

Vol. 2, No. 7, pp. 181-226, Pls. 19-20 December 16, 1905

TERATOLOGY IN THE FLOWERS OF TWO CALIFORNIAN WILLOWS

BY

WILLIAM WARNER MOTT

CONTENTS.

PAGE

I. Introduction 181
II. A Teratological, mainly Staminate, *Salix lasiolepis* Benth. 184
III. A Teratological, mainly Pistillate, *Salix lasiandra* Benth. × *babylonica* L. and some related individuals 196
IV. Bearing of the Abnormalities described on some Moot Points regarding the *Salix* Flower 203
V. Some Possible Causes of the Abnormalities described 209
VI. Summary 213
VII. Bibliography 216
VIII. Explanation of Plates 219

Introduction.

The normal flowers of the numerous species of willows are unisexual, and the staminate and the pistillate flowers are born on separate individuals (species dioecious). There is no perianth, but the flowers are born in catkins, and the bracts of a catkin closely subtend the sex-organs composing the flowers and protect these organs in the young stage. The number of stamens in a flower varies in different species, but two, three, or five are common. The pistil is unicellular and bicarpellary with two parietal placentae, and the fruit is a capsule. A small honey-gland is borne at the base of the pistil and of the stamens, on the side next to the axis of the catkin, and in some species a second basal gland is borne on the bract opposite to the first.

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Cases of monoecism (male and female flowers on one individual), and of abnormal bisexual flowers with perfectly developed pistil and stamens, and of flowers with monstrous sex-organs combining the characters of pistil and stamens in various proportions have been frequently recorded in this genus (*Salix*) and several writers have speculated at some length as to the cause, and as to the significance, morphological, anatomical, and physiological, of these abnormalities. A few of the articles published have been accompanied by illustrations, notably a paper by Camus (1899) and two by von Seemen (1886, 1895), but none of the drawings show *in detail* a series of the monstrous organs connecting stamens and pistil. The object of this paper is mainly to present drawings of such a series with particular note of certain facts well shown by the material at hand, some of which have not been found described elsewhere. The material was discovered by the writer on a predominantly male individual of *Salix lasiolepis* Benth. (near Berkeley, in the spring of 1903). The male tree of this species has normally two stamens to a flower, and this abnormal specimen showed* the two stamens in various stages of transformation (so it appeared) into pistil. The converse case of apparent transformation, namely, pistil more or less changed into stamens, has also been found by the writer on a predominantly pistillate willow-tree,† which is believed to be a hybrid of *Salix lasiandra* Benth. and *Salix babylonica* L.; and on this tree occurred also bisexual flowers with perfectly developed pistil and stamens (the number of stamens being commonly two), and also two extra, lateral floral glands. Some notes of these abnormalities are made.

This pistillody of the stamens and staminody of the pistil, and the occurrence of bisexual flowers with normally developed sex-organs have not, it is believed, been hitherto reported in *Salix* for this Coast, nor, therefore, for this species and this hybrid. Also no mention has been found for this genus of the intimate association, which is shown here in the *Salix lasiolepis*

* The tree was destroyed soon after it was found, by the opening of a street.

† The tree is still growing, near Berkeley. It was found the same season as the *S. lasiolepis* first mentioned.

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series, of the micro- and macrosporangial tissues,—ovules protruding through pollen-sacs, and causing malformations in their walls.* Likewise there seems to be no record for *Salix* of the occurrence of four floral glands in a flower.

The possible bearing of the irregularities described upon several matters of discussion regarding the genus *Salix* will be briefly indicated,—such questions, for example, as whether the ancestral flower was perfect,† instead of unisexual, or whether even complete; ‡ what, if the flower were perfect, was the number of stamens; and whether the two carpels of the now normal pistil stand median § or transverse.‖

The facts described seem of interest, too, in connection with a wider biological question of what, in general, causes to be produced, from the apparently common undifferentiated tissue, in one case, pistil, in another, stamen, in another, leaf, stem, or root,—the question, that is, of what are the determining factors in the development of this embryonic basal tissue which seems to possess the potentiality of producing all forms of organ-tissue peculiar to a species.

The occurrence of bisexual flowers with distinct pistil and stamens, on these willows, in place of normal unisexual flowers, and the abnormal development of ovules, female bodies, instead of pollen-sacs, male bodies, and also of both ovules and pollen-sacs at once, from the embryonic tissue of the connective, are matters of interest in connection with the general problems of sex,—not only in the plant world but in the animal world as well. In the animal world, also, cases of casual and of normal hermaphroditism, of different degrees of intimacy, occur.

The perfect flowers with distinct pistil and stamens suggest, among animals, the case of one of the toads, the male of which

* Two cases somewhat similar, of polleniferous ovules in passion-vines (Passiflora coerulea and P. palmata) have been described and illustrated by Salter (*Trans. Linn. Soc.* XXIV, p. 143, tab. XXIV), and a case of the same monstrosity in a rose (Rosa arvensis) has been reported by Masters (Seemann's *Journal of Botany*, 1867, p. 319, tab. LXXII, figs. B 1–9). An instance of ovuliferous anthers in a gourd (Cucurbita) is mentioned by Berkeley (*Gard. Chron.* 1851, p. 499.)

† Perfect: having the essential organs, viz. pistil and stamens.

‡ Complete: having pistil, stamens, and also perianth.

§ Median: in the line of the bract and the axis of the ament.

‖ Transverse: in a line at right angles to the median line.

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has frequently a rudimentary ovary in front of the testes, and again the case of the leech, which has regularly both ovaries and testes in one individual, the two sets of organs being quite distinct from each other. Many fishes, such as the cod, and, a little lower, the hagfish are often similarly hermaphrodite.

The case of the monstrous bisexual floral organs, where pollen-sacs and ovules develop with apparent indifference from connective tissue, is similar, in some measure, to the case of the regularly hermaphrodite snail, where sperm and ova are derived from identical cells originating in the so-called hermaphroditic gland, the sexual differentiation of these reproductive cells depending merely upon which of two glands they are conducted into for their development.

In degree of anatomical intimacy, the hermaphroditism seen in the monstrous floral organs,—where the seats of pollen-sac- and ovule-production are so very close together on one phyllome, —is analogous to that bisexualism occasionally found in the common frog, where a testis may have an anterior ovarian portion, or an ovary be anteriorly replaced by a testis.

These cases, then, of sexual abnormality among plants, like the similar instances among animals, bear upon various general questions of sex:—is hermaphroditism the primitive condition in all organisms; and are male and female sex-elements,—microspores and macrospores, sperm and ova,—universally developed by differentiation of sexless cells, or, better perhaps, of cells potentially of either sex; and so on. The facts here noted may prove of interest in some such connection.

A Teratological, Mainly Staminate, *Salix lasiolepis* Benth.

PISTILLODY OF THE STAMENS:—DESCRIPTION OF A SERIES OF SEXUAL ORGANS CONNECTING THE TWO STAMENS (THE TYPICAL MALE FLOWER OF THE SPECIES) WITH A BICARPELLARY PISTIL (THE TYPICAL FEMALE FLOWER OF THE SPECIES).—This series of forms showing increasing amounts of pistillody of stamens is represented in the series of figures on plates 19 and 20 (figs. 1–15). Only enough of the abnormal forms are shown to make evident

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the connection between stamens and pistil; numberless other phases might have been interpolated. Figures 1 and 15 are from normal trees, as types of the male and female flowers, for comparison. The various forms that occur in this abnormal tree, it is well perhaps to state clearly at once, are found composing as many distinct flowers. That is, a given pair of sexual phyllomes do not go through a transformation from a perfectly developed pair of stamens, to a perfectly developed pair of carpels forming a pistil, but remain constantly of the general character that marks them in the floral bud, * until they finally fall with the catkin. However, for the sake of vividness in bringing out certain points that are shown by the series of forms, the different members of the series are described as though each represented a temporary stage in a progressive change from stamens to pistil taking place in a single flower. To follow a description of such a process of change it is well perhaps first to have more clearly in mind the initial and final stages.

The normal staminate flower in this species (cf. pl. 19, fig. 1) consists of the two stamens, standing transverse, with cylindrical filaments more or less united. The amount of union of the filaments is variable in the species. In the flower chosen to show the normal type, the filaments are united about to the middle as in the case of the most nearly normal staminate flowers on our abnormal tree. The anthers are adnate,—that is, attached by their whole length to the ends of the filaments. Each anther is composed of four pollen-sacs (or microsporangia), in two pairs, the two pollen-sacs of a pair being closely united to each other, and shedding pollen through a single slit. The anthers in the young stage are back to back (extrorse) (cf. fig. 1A, pl. 19), but by the time they are ready to shed their pollen, they have turned, through torsion of the filaments, to face the honey-gland.

The normal female flower (cf. figs. 14 and 15) consists of the unicellular, bicarpellary pistil. The two carpels stand—it

* Whether a pair of phyllomes which are finally, at least, abnormal undergo such a change, more or less completely, in the very young stage in the floral bud, or whether the pair are abnormal from their very inception at the meristem—these are points apparently still to be worked out.

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is commonly considered—transverse, like the stamens. The stalk, or stipe, is short. The two placentae are median, and on the walls of the ovary (parietal), and only on the lower part of the walls (see fig. 13). The number of ovules is from six to eight. The upper barren portion of the ovary is tapering, and affords space for the tufts of hair arising from the ovule stalks, or funiculi. The style is single and rather short, and the stigma is more or less bilobed transversely. Two longitudinal seams, one in the anterior * wall of the ovary and one in the posterior † wall, mark the sutures between the two carpels and, as well, the position of the two placentae within. Two slight longitudinal grooves, on the right and left sides of the ovary, follow the midribs of the carpels. It is along these lateral grooves, and not at the sutures, that dehiscence occurs (dehiscence loculicidal, see fig. 12); hence the two valves of the capsule are median and the seeds are found on the middle of the valves.

The change from stamens to pistil is effected, in brief (a detailed description follows later), by a median broadening and also an apical development, and final union, of the two connectives, to form the ovary of the pistil—(1) the lower ovule-bearing portion and (2) the upper barren portion—and also (3) the style and (4) the stigma, and further by a shortening, and completion of the fusion, of the filaments, to form the stipe of the pistil. The vegetative broadening of the connectives occurs in such a way as, at an early stage in the series, to throw the reproductive portions inward, so that the anthers, which are produced from these portions, are, in the young stage, face to face (introrse) (though normally extrorse) and the ovules, produced from the same reproductive regions, are, finally, enclosed when the connectives unite. The change in the general form of the phyllomes from that of a stamen to that of a carpel is proportional (with some latitude) to the degeneration of the pollen-sacs, and the replacement of them by ovules. That is, all the male characters of the phyllome, being correlated, vary approximately together, and the female characters the same.

* Anterior: toward the bract.

† Posterior: toward the axis of the catkin.

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The two phyllomes of a flower usually show the same amount of change, but they may differ somewhat. Dehiscence of the ovary, so long as it is monstrous to the extent of bearing anthers, or anther-vestiges, is premature and at the sutures, so that the *transversely* standing phyllomes remain intact; after the anthers have quite disappeared, the dehiscence is no longer premature, and it occurs at the midribs (as in the flower on the normal tree) so that the two valves of the capsule are *anterior* and *posterior*.

A detailed account of this change from stamens to pistil is best given by describing in order the forms represented in the series of drawings. Various facts that are exhibited by the series as a whole, or by certain parts of it, will be touched upon under those figures that are most suggestive of the particular facts. In all the figures, it is the posterior side of the flower which is shown,—the side toward the axis of the ament. The bract, honey-gland, and lower part of the united filaments are in most cases not shown. Most of the figures are about ten times natural size.

Fig. 1. This is a typical staminate flower from a normal tree. It has already been described. The four pollen-sacs of each anther are seen to be closely associated. Later on in the series, these pollen-sacs, or microsporangia, degenerate, and the vestiges often stand independent of each other, as their prototypes in the Gymnosperms and Cryptogams quite commonly do. Fig. 1A shows a young diandrous flower (*S. purpurea* L.) with extrorse anthers.

Fig. 2. This is the nearest approach to absolutely normal flower that is found on the tree. It is a very common type. The free ends of the two filaments (which we will call the "forks") are apparently never perfectly cylindrical but are always slightly grooved longitudinally on the sides that face each other. These two grooves are the first indications of the formation of the ovarian cavity of the pistil. As has been said, however, it is the *connectives* which form the ovary, and later in the series, these forks cease almost entirely to be developed, the pair of filaments as a whole shortening to become the stipe of the pistil. These two grooves at this stage arise as follows:—

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While in the floral bud (and these first remarks are true of stamens in general) the filaments attain about their full development in thickness, but remain very short, until the anthers have reached almost their full size and are nearly ready to discharge their pollen. This keeps the anthers within the protection of the bract as long as possible. Just before dehiscence of the pollen-sacs, the cells of the filaments increase greatly in length, so that the anthers are exserted and the pollen is rendered accessible to insects. Now while these abnormal stamens are still in the bud, and the filament forks are short (remembering that the anthers of the abnormal phyllomes, at least while young, are introrse as explained later) there is a hollow on the inner side of each fork, at the base of the anther. The presence of this hollow is due to the fact that the connectives, which bear the anthers directly, have commenced to become grooved on the inner sides preparatory to the formation of the concave ovary walls, and this grooving has extended downward into the short filament forks. Hence as the cells of the forks lengthen, these slight hollows develop as grooves along the whole length of the forks.

The anthers here have twisted to face the honey-gland, and the flower is otherwise normal.

Fig. 3. The forks and connectives here are broadened somewhat, medianly, and the grooving, or concaving, is more pronounced. The anthers, which are still, from the bud, largely facing each other, are seen to be introrse in their position on the connectives; that is, the four reproductive portions of each broadening connective, and hence the four pollen-sacs, have been brought to face inward. This change is anticipatory of the production of ovules—which are to come from these same reproductive portions—for the ovules are finally to be enclosed by the union of the broadened connectives.*

* The fact that the anthers in these abnormal forms are introrse, at least in the young stage, instead of extrorse as in the normal flower of the species, it is possible, it seems, to account for as follows:

In the young stamens—and this is true of stamens in general of this simple *Salix* type—the four pollen sacs, or microsporangia, are produced by a differentiation longitudinally of the tissue at the end of the stamen. Two pollen sacs are formed in the anterior angles of the stamen, one right

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The anthers are seen to have commenced to twist, mainly through mere torsion of the forks, to face toward the honey-gland. The tendency of the anthers to assume this position, when they are mature, is present in the normal flower, and is shown all through the series of abnormal forms as long as any trace of the pollen-sacs remains. The advantage of the position for insect pollination is obvious.

The posterior margins of the forks are ununited. Either the twisting of the anthers to face the honey-gland has torn them apart, or else the swelling of the still well-developed anthers prevented them from ever uniting. This condition, namely, of intact anterior suture and prematurely ruptured, or never formed, posterior suture,—is common in these monstrous forms especially later in the series. In the earlier forms of the series, while the anthers are still well developed, there is usually no union of the forks at all.

Fig. 4. This figure shows the first appearance of ovules, and the ovules are seen to be close to the basal end of the anther-lobes. Only one of the stamens bears them. The two phyllomes of a flower are not infrequently different in character to the extent shown here. The right stamen is similar to both phyllomes in fig. 2, though the groove is a little more evident. The left fork has reached a little further developed stage. The ovules are seen to point inward. There is only one ovule, as yet, on each margin of the phyllome. The normal number on each

and one left, and two in the posterior angles, one right and one left, the portion of the stamen between the two pairs being the "connective." The position of the pollen-sacs in the mature state of a stamen is often different from this, owing to the later vegetative processes of growth in the stamen-tissue, especially in the region of the connective. These are well-established facts. Now in the normal flower of this diandrous willow, the two stamens are close together, and it is apparently because the pollen-sacs crowd against each other as they develop and swell with pollen, that they come to face outward, or become extrorse. In the bud, the two extrorse anthers, standing close together, appear as in fig. 1A, pl. 19. In the series of abnormal forms, where the two connectives gradually become broadened medianly to form the concave ovary-wall, it is apparently because the vegetative increase necessary to effect this broadening is greatest on that side of each connective which is farthest from the other connective, that the four pollen-sacs are thrown to face inward, or become introrse.

The connectives in fig. 3 are not yet greatly broadened but there seems to have been sufficient growth on their outer sides to throw the pollen-sacs inward.

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margin of a carpel is three or four, since the normal number on each placenta of the pistil is six or eight and the placenta is formed by the union of two carpel margins. That these two bodies are undoubtedly ovules is shown by the enlarged drawing, fig. 16. This drawing represents an optical, longitudinal, median section of one such body through the raphe. A similar section of an ovule from a pistil borne on a normal tree is identical with this. The characters are unmistakable:—central nucellus enclosed by two coats (integuments), basal micropyle (ovule anatropus), and raphe, or prolongation of the stalk (funiculus), with its vascular bundle terminating at the (chalaza) base of the two coats.

Fig. 5. Here the number of ovules has increased, and the placental vascular strands have become evident as thickenings on the margin of the forks. The vascular bundle in a normal stamen is so little developed as scarcely to be detected, for only enough nutritive material has to be conducted to the pollen-sacs (microsporangia) to bring them to maturity, while to the ovules (macrosporangia) sufficient food has to be conducted not only to bring them to maturity as macrosporangia, but also to supply their demands, after their fertilization, by the pollen, while they are being developed to maturity as seeds.

There is an ovule at the base of each half-anther, or anther-lobe, and the bodies *a* and *c* are ovules even *protruding through* the anthers, so closely are the ovules associated with the pollen-sacs in the production of both from the reproductive portions of the phyllomes. In fact it is this close association, which is seen commonly in the forms of this type, that shows that it is a fairly definite part of a phyllome which is reproductive. In other words, the connective region of the stamen and the placental regions of a carpel seem to be homologous.

The small bodies higher up, in the sinuses, or furrows, in the face of the anthers, where two pollen-sacs unite to form a half anther,—bodies which look like ovules,—are in reality lobes in the walls of the pollen-sacs. There seems to be no question that these lobes are caused by abortive ovules beneath, for though in most cases there is nothing but pollen within such lobes, in

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some instances there is a slight protuberance on the connective beneath; and an ovule, in general, originates in this way. The cases such as seen here (noted above) of ovules actually protruding through pollen-sac tissue, are further evidence that the lobes are caused by incipient ovules. The tissue *b*, for example, around the base of the protruding ovules *a* is unmistakably anther-tissue, and it would doubtless have constituted a lobe only that the ovule succeeded in keeping from being overwhelmed, as ovule and pollen-sac developed together; that is, the crowding of the anther-tissue here was partially withstood by the developing ovule, while in other cases anther-tissue gained almost complete supremacy, and yet lobes in the pollen-sac walls were caused by the overwhelmed ovules.*

The pollen-sac lobe *d* looks particularly like an ovule; it stands out in the sinus almost independent of the main portion *j* of the pollen-sac. The lobe *e* on the right half of the right stamen, on the other hand, is merely a slight elevation in the surface of the wall of its pollen-sac. Other lobes (also marked *e*) are more or less intermediate in form. (The means of identifying pollen-sac tissue are seen in figs. 17–19, and the matter of this identification is further referred to under fig. 7.)

The right anther lobe has dehisced.

Fig. 6. The forks and connectives in this figure have become considerably broader, and here, on the left phyllome at *c*, is seen the first indication of apical development of the connective to form the upper barren portion of the ovary, and the style and stigma. The right connective is not yet so developed. (The ovules are usually produced nearer to the anthers than shown here.)

Fig. 7. The right phyllome here is still predominantly stamineal, the anther being well developed, and the fork elongated. The left phyllome, however, is about equally divided in character between stamen and carpel. The anther has been reduced to vestiges, and the fork accordingly is only partially developed,

* These effects of pollen-sacs and ovules upon each other, where they are produced together, are such as one might expect, in consideration of the processes by which pollen-sacs and ovules, in general, are produced by differentiation of embryonic tissue of stamen and carpel respectively.

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though the united part of the two phyllomes is still of the normal length in the stamen. The development of pollen-sacs and the elongation of the cells of the filament are correlated male characters of the phyllome, and the development and the elongation vary in amount approximately together. The lengths of the cells of the two forks in this case were found to be about inversely proportional to the lengths of the forks. On the left phyllome, ovules have almost entirely supplanted the right lobe of the anther, all that remains of the lobe being the vestige *d*. At the same time, there has occurred a considerable apical development of the connective toward the formation of the upper pistil-parts (barren portion of the ovary, style, and stigma), this being a female character of the phyllome correlated with the production of ovules. The ovules here are all well developed. The beginning of the upper barren portion of the ovary is seen at *h'*, the style at *h*, and the stigma at *i*. The styles and stigmas of the two phyllomes unite later on. The style here, being still free, has shriveled and curled downward.

The body *d* on the left phyllome might be taken superficially for an ovule, it being minute and otherwise similar to an ovule, and being borne among ovules, but it proves under the higher power of the microscope to be a pollen-sac vestige; just as the still more ovule-like body *d*, pl. 19, fig. 5, proved to be of pollen-sac tissue. Even under the lower power, the ovules appear slightly fluted longitudinally and the oblong shape indicates the polarity they possess; while the pollen-sac lobes and even the least developed pollen-sacs have a smooth surface of small polygonal cells such as normally developed pollen-sacs have. Pollen-sac lobes and vestiges also often contain grains of pollen, normal at least superficially (see pl. 20, fig. 18), (though these are often lost in dissecting out the body for examination). Under the higher power, *d*, for example, shows the cellular wall structure which is characteristic of the normally developed pollen-sac. This peculiar structure is illustrated by figs. 17 and 19. The wall is composed of an outer layer of thin-walled cells and an inner layer of so-called fibrous cells. On approaching maturity, the outer layer dries more rapidly than the inner, and contracts

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more (as does the drying film of clay over coarser material on the site of a recent pool), and the rupturing along the weakest line, namely, the suture between two pollen-sacs, is dehiscence. Hence the identity of ovules and of pollen-sac vestiges and lobes is established.

Fig. 8. The connectives here are broadened almost to the full amount; the anterior margins are united; a style and stigma have developed from each connective, though they are malformed and the styles and the stigmas are still ununited; the old filament forks are both reduced, though the old united portion of the filaments is still longer than a stipe. The anthers at this stage are usually more degenerate. There is about a normal number of ovules, on the anterior placenta. The ovarian cavity is well developed, though the posterior margins of the phyllomes (which were very likely united in a younger stage) have been torn apart. This figure illustrates the fact that the monstrous ovary dehisces prematurely and at the sutures, instead of at the midribs.

Fig. 8. The connectives have now both reached full carpel-width, both anterior and posterior margins have united below, though the upper parts are still free. The tapering upper portion of the ovary is not yet well developed, and the figure shows (better than the last) a rather common persistence of abnormality of style and stigma. The anthers have become so nearly eliminated that dehiscence is no longer premature, and yet seeds are not matured, the organ falling early. As a whole, the two phyllomes have come to suggest pistil rather than pair of stamens.

Fig. 10 shows close approximation to normal pistil. The phyllomes are wholly united, the ovary is tapering above, and style is single and there is clear demarcation of the style from the ovary. The lobing of the stigma, however, is still right and left, corresponding to the original stamens, and not yet to the valves. The stipe is still abnormally long. (Even though, however, the lobes of the stigma in the normal pistil in this species commonly correspond to the valves, dehiscence does not extend through the style and stigma, but style and stigma either fall intact from the ripe capsule or else break away from one valve at the time of dehiscence, and remain attached to the other.)

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Fig. 11 shows the same specimen as fig. 10, but with the nearer (posterior) half of the ovary removed, to show that the pollen-sacs have completely disappeared, and that the ovules are in their normal position: that is, they are median, for they are borne on the margins of transverse phyllomes, as we have seen in the preceding figures; and they are on the lower part of the ovary-wall, for the old filament forks—below the reproductive portion of the phyllomes—have been reduced and at the same time the old connectives—the reproductive portions themselves—have been developed apically to form the upper barren portion of the ovary-wall.

Fig. 12 shows the completion of the change. The stipe is of normal length, the ovary has swollen with seeds and down, and has matured as a normal capsule dehiscing at the carpel midribs so that the valves are anterior and posterior. Style and stigma have fallen away. The valves separate as normally, only half or two-thirds of the way down.

Fig. 13 presents the anterior valve of the capsule in fig. 12, pl. 20, with basal remnants of the other valve, to show the characteristic position of the placenta,—median and at the lower half of the suture between the phyllomes.

Fig. 14, showing a pistil from a normal tree, has already been described. It exhibits the typical characters which we have seen developing through the series. The view of the pistil is posterior, as in the preceding figures, for the sake of comparison.

Fig. 15 shows the same flower as in the last figure, but turned somewhat to bring into view one of the slight grooves at the carpel midribs along which normal dehiscence occurs, as contrasted with the abnormal dehiscence at the sutures in the monstrous forms.

There is thus a complete series of forms on this abnormal *Salix lasiolepis* connecting, by slight gradations, a pair of stamens and a bicarpellary pistil.

MANNER OF OCCURENCE OF THE ABNORMAL FLOWERS ON THE CATKINS, AND EFFECT OF THEIR PRESENCE ON THE TIME OF FALLING OF THE CATKINS.—The flowers abnormal to the tree are, of

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course, both those with any form of monstrous hermaphrodite organ and also those with perfectly developed pistil, for the tree as a whole was evidently predominantly staminate. The predominance of the male character of the tree as a whole was shown by the fact that when the tree was in full bloom, anthers were commonly enough present in the flowers to give almost as much of a yellow cast to the tree as is characteristic of the normal male individual. Many of the catkins were composed wholly of practically normal male flowers, but the majority of the catkins were made up of monstrous hermaphrodite flowers which yet were more staminal in character than pistillary. Quite a large number of catkins which were chiefly of monstrous flowers showed more of a green cast than yellow, the majority of the sex-organs here resembling pistils rather than pairs of stamens. Again a considerable number of catkins were composed wholly of perfectly developed pistillate flowers. Then in addition to these four sorts of catkins named, composed wholly or mainly of one type of flower, there were many catkins showing combinations of these types of flowers in various proportions; and the different types occuring on a given catkin might be rather thoroughly intermingled, or might be in different parts of the catkin (as base, middle, and tip), but without any regularity as to which type occurred on any part.

The presence of monstrous sex-organs on a catkin tended to cause the catkin to drop early,—earlier even than a wholly male catkin drops. In general, of course, male catkins of the willow fall earlier in the season than the female, for the function of the staminate catkins in fulfilled earlier,—that is, as soon as the matured pollen is shed,—while the pistillate catkins must persist, after this escaped pollen has fallen upon the stigmas, until the seeds have matured and scattered. These monstrous hermaphrodite organs, however, unless very predominantly of one sex or the other, soon shriveled after the opening of the flowers, so that catkins wholly of monstrous flowers soon fell after blooming. The majority of the catkins borne by the tree being of the decidedly monstrous type, the tree as a whole had few catkins hanging upon it at a time (March 26) when normal male individuals near by still had many catkins on them in bloom.

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IN

BOTANY

WILLIAM ALBERT SETCHELL

EDITOR

VOLUME 2

WITH 29 PLATES

BERKELEY
THE UNIVERSITY PRESS
1904-1907

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About 6 o'clock in the evening the steamer leaves the wharf at San Francisco and proceeds up the bay and thence up the river. As it ascends the river the water gets gradually fresher, so that some hours after leaving San Francisco the algæ are in perfectly fresh water. In this they remain for a period of about twenty-four hours, during which time the steamer goes to Stockton, and returns down the river again to the point where the fresh water begins to be mixed with salt water.

The daily changes to which the algæ are subject include the extremes of perfectly fresh water on the one hand and saturated sea-water on the other. The difference between the maximum and minimum temperature to which they are exposed during a single day may amount to 70 or 80 degrees Fahrenheit.

Oltmanns and others have taken it for granted that marine algæ are very sensitive to fresh water, and that even a small dilution of sea-water with fresh water suffices to injure or kill them. In this way they have explained the distribution of algæ near the mouths of rivers. It is very evident that in the case of the algæ here described no such explanation can be given, and it may be questioned whether such an explanation is of general application.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
BOTANY
Vol. 2, No. 9, pp. 229–230 March 15, 1906

THE RÔLE OF OSMOTIC PRESSURE IN MARINE PLANTS.[1]

(*Preliminary Communication.*)

BY
W. J. V. OSTERHOUT.

The experiments of Loeb[2] have shown the incorrectness of the prevailing view that the death of marine animals when placed in distilled water is due to lack of osmotic pressure. He found that these animals died as quickly in a solution of cane sugar isotonic with sea-water as in distilled water. He has furthermore shown that certain marine animals (Fundulus) develop as well in distilled water as in sea-water.

Such facts have not been observed upon plants. It is generally believed that marine algaæ require a definite osmotic pressure to enable them to live, and that this pressure cannot be suddenly altered to any great extent without serious consequences.

Some experiments which I have recently made have convinced me that marine algæ in general are not so sensitive in this regard as is commonly supposed, and that in certain cases osmotic pressure plays a very subordinate rôle in their life processes. Three of the marine plants investigated have proven especially interesting in this regard. They are Lyngbya aestuarii, Enteromorpha Hopkirkii and Ruppia maritima. They grow in a ditch in a salt marsh through which the tide ebbs and flows. There is

[1] It gives me much pleasure to express my thanks to Professor Loeb, who kindly placed the facilities of his laboratory at my disposal for the experiments described in this and in the two following papers.

[2] Pflüger's Archiv, 97, 394, 1903. Am. Jour. Physiology, 3, 327, 1900.

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always a foot or so of water in the ditch even at low tide. The mean salt content of the water is about 2.3 per cent.

These plants when brought into the laboratory live for months in ordinary sea-water. If placed in distilled water[1] (after first being carefully rinsed for two or three hours in several changes of distilled water) they live a month or more. Ruppia is able to live in distilled water two or three months. In tap-water they live still longer than in distilled water.

If the plants are transferred from ordinary sea-water directly to saturated sea-water (prepared by allowing sea-water to evaporate in glass dishes until crystals just begin to form) they live from one to two months.

If the plants are placed in shallow glass dishes with a very little sea-water and allowed to stand, the sea-water becomes saturated in a few hours and the plants become covered with crystals. In this condition they may remain alive three to five months, or nearly as long as in normal sea-water.

If marine algæ which are ordinarily regarded as most delicate and sensitive, such as Ptilota filicina, Pterosiphonia bipinnata, Nitophyllum multilobum, Porphyra naiadum, Plocamium coccineum and Ectocarpus confervoides, are subjected to the treatment just described, they live as long or nearly as long as in ordinary sea-water.

Another interesting fact is that all of the algæ mentioned live nearly as long in sea-water to which three or four volumes of distilled water have been added as in ordinary sea-water.

These facts (together with those set forth in the preceding communication) serve to show how small a rôle osmotic pressure plays in the life processes of many plants which are generally supposed to be very sensitive to changes of osmotic pressure.

[1] The water used must be distilled in glass only, since that distilled from metal is poisonous.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
BOTANY
Vol. 2, No. 10, pp. 231-234 March 15, 1906

ON THE IMPORTANCE OF PHYSIOLOGICALLY BALANCED SOLUTIONS FOR PLANTS.

(*Preliminary Communication.*)

BY
W. J. V. OSTERHOUT.

Ringer demonstrated that animal tissues live longer in a solution of NaCl to which a small amount of KCl and $CaCl_2$ is added than in a solution of NaCl alone. Various explanations of this fact have been given by different investigators, all of whom, however, agree upon the essential point that KCl and $CaCl_2$ are essential for the maintenance of life.

Howell assumes that $CaCl_2$ is the stimulus for the heart-beat while NaCl is an indifferent substance, necessary only for the maintenance of osmotic pressure. Similarly Ringer concludes that Ca is the stimulus for the systole while K is necessary for the diastole of the heart-beat.

Herbst has made experiments on the influence of the composition of the sea-water on sea-urchin eggs, eliminating in each successive experiment a different constituent of the sea-water. He found that the eggs would not develop in any solution which did not contain all the salts of the sea-water. From this he concludes that each of the salts found in sea-water is necessary for the development of the egg. Loeb has called this view in question as the result of his experiments on Fundulus. He finds that this marine fish cannot live in a pure NaCl solution of the same

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osmotic pressure as the sea-water, but that it can live indefinitely in a mixture of NaCl, KCl, and $CaCl_2$, in the same proportions in which these salts are contained in sea-water. The fish can also live indefinitely in distilled water. This proves that it does not need any of the three salts mentioned for the maintenance of its life, and that the Ca and K are only required to overcome the poisonous effects which would be produced by the NaCl if it alone were present in the solution (at the above mentioned concentration).

It is noteworthy that the Ca and K which are added to inhibit the toxic effect of NaCl are themselves poisonous at the concentration at which they are here employed.

These antagonistic effects of Ca and K toward a pure NaCl solution were illustrated still more strikingly in experiments on the egg of Fundulus. The newly fertilized eggs of this fish develop equally well in sea-water and in distilled water, but die in a pure ½-M NaCl solution without forming an embryo. If, however, a small but definite amount of a salt with a bivalent cation, even of such poisonous salts as $BaCl_2$, $ZnSO_4$ and $Pb(CH_3COO)_2$ is added, the eggs will produce embryos. From these and similar observations Loeb was led to formulate his conception of the necessity of physiologically balanced salt solutions in which are inhibited or counteracted the toxic effects which each constituent would have if it alone were present in the solution.

The blood, the sea-water, and to a large extent Ringer's solution are such physiologically balanced salt solutions. The observations of Herbst as well as those of Ringer are easily explained on this basis. The fact that the elimination of any one constituent from the sea-water makes the solution unfit to sustain life does not prove that the eliminated substance is needed by the animal for any purpose, other than to counteract the poisonous action of some other constituent of the solution.

Botanists have not thus far made use of these conclusions, for the obvious reason that facts similar to those mentioned above have not been observed in plants. I have recently made a number of experiments which show that there exist in plants phenomena similar to those observed by Loeb on Fundulus and other animals.

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The species of marine plants chosen for investigation may be divided into two groups.

Group 1 comprises plants which can live a long time in distilled water. Group 2 is composed of plants which quickly die in distilled water.

1.—The results of the experiments on Group I are as follows:

(*a*) The plants die much sooner in a pure sodium chloride solution (isotonic with sea-water) than in distilled water. The poisonous effect of the NaCl largely disappears if we add a little $CaCl_2$ (10 c.c. $CaCl_2$ 3/8 M to 1,000 c.c. NaCl 3/8 M); in this mixture the plants live nearly as long as in distilled water. Addition of KCl to this mixture enables them to live longer than in distilled water. Further addition of $MgCl_2$ and $MgSO_4$ enables them to live practically as long as in sea-water.

(*b*) The pure solution of each of the salts added to inhibit the poisonous effects of NaCl is itself poisonous at the concentration[1] at which it exists after its addition, since the plants die in such a solution much sooner than in distilled water.[2] A mixture of solutions which are individually poisonous produces a medium in which the plants live indefinitely.

(*c*) The poisonous effect of NaCl is inhibited little or not at all by KCl or $MgCl_2$ added singly.

(*d*) The combination $NaCl + KCl + CaCl_2$ is superior to $NaCl + MgCl_2 + CaCl_2$, but the latter is usually better than $NaCl + MgCl_2 + KCl$.

(*e*) These effects must be due to the metal ions, since the anion is in nearly all cases the same.

2.—The plants of Group II agree with those of Group I except in their behavior toward distilled water.

3.—Essentially similar results were obtained from the study of fresh-water plants (including algæ and flowering plants) as well as from the study of the gemmæ of Lunularia.

[1] That death is not due merely to the lowered osmotic pressure of these solutions is shown by the fact that in tap water (which has a lower osmotic pressure than any of them) the algæ live longer than in any of the solutions containing but a single salt (the only exception being $CaCl_2$ solutions in some instances).

[2] An exception to this statement is found in $CaCl_2$, which is not toxic for many forms in dilute solutions.

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These results agree in striking fashion with those obtained from the study of marine[1] and fresh-water animals[2].

The combination $NaCl + KCl + CaCl_2$ (in the same proportions as in sea-water) seems to be universally beneficial for animals and plants. The substitution of $MgCl_2$ for either KCl or $CaCl_2$ has usually a more or less injurious effect.

We may in conclusion briefly consider the effects of concentrated solutions. A series of experiments were made on Enteromorpha Hopkirkii in which the plants were placed in dishes with a very little sea-water. This quickly evaporated so that the plants became covered with salt-crystals in from twenty-four to forty-eight hours. In this condition some of them remained alive for about 150 days. This means that Enteromorpha plants which remain alive only fifteen days in 3/8 M NaCl solution can live 150 days in an NaCl solution of ten to twelve times higher concentration, provided the other salts of the sea-water are present in the solution (at corresponding concentration) to inhibit the toxic effect of NaCl. Experiments on Lyngbya, Ptilota and Pterosiphonia gave essentially the same results.

RESULTS.

1.—Each of the principal salts of the sea-water is poisonous where it alone is present in solution. This applies to both marine and fresh-water plants.

2.—In a mixture of these salts (in the proper proportions) the toxic effects are mutually counteracted. The mixture so formed is a physiologically balanced solution.

3.—Such physiologically balanced solutions have the same fundamental importance for plants as for animals.

---

[1] Loeb: Pflüger's Archiv, 107: 252, 1905, and the literature there cited.
[2] Ostwald: Pflüger's Archiv, 106: 568, 1905; Univ. of California Publications, Physiology II:163, 1905.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS
BOTANY
Vol. 2, No. 11, pp. 235-236 March 15, 1906

THE ANTITOXIC ACTION OF POTASSIUM ON MAGNESIUM.

(*Preliminary Communication.*)

BY
W. J. V. OSTERHOUT.

That the poisonous effect of a salt may disappear when another is added has long been known to animal physiologists. The chief worker in this field is Loeb, who has brought to light a large body of unexpected facts. The only plant physiologist who has called attention to such phenomena is Loew, who has laid emphasis on the fact that calcium is strongly antagonistic to magnesium. His researches and those of his pupils have shown that the poisonous effects of magnesium disappear upon the addition of small amounts of calcium.

In his researches and practical applications of them to soils Loew practically ignores the possibility that the poisonous action of magnesium may be counteracted by other substances than calcium. From his experiments on Spirogyra, Loew concludes that the poisonous action of magnesium can not be antagonized by either sodium or potassium.

Inasmuch as the soil contains large quantities of sodium and potassium, it would appear that these elements should merit especial consideration.

In a series of experiments on aquatic plants, both fresh water and marine, I have found that the poisonous action of magnesium may be antagonized by potassium, but not by sodium.

It was found, for example, that Spirogyra, which lived indefinitely in distilled water, was killed in less than twenty-four

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hours in a solution of $MgCl_2$ 3/32 M, and in thirty-six hours in a solution of $MgCl_2$ 3/320 M. If, however, to 40 c.c. 3/8 M $MgCl_2$ solution we add 100 c.c. 3/8 M KCl and 20 c.c. H_2O, the plants live forty-seven days. This fact is the more striking inasmuch as KCl 3/32 M is itself poisonous and kills the plants in less than twenty-four hours. On the other hand it was found that the addition of NaCl in various proportions up to 1,000 c.c. NaCl 3/32 M to 40 $MgCl_2$ 3/32 M did not counteract in any degree the poisonous effects of $MgCl_2$.

The case is similar with gemmæ of Lunularia, which live almost indefinitely in distilled water. They are killed by $MgCl_2$ 3/32 M in three days or less, and by $MgCl_2$ 3/320 M in five days or less. But if to 40 c.c. $MgCl_2$ 3/32 M we add 100 c.c. KCl 3/32 M and 20 c.c. H_2O, they live over fifty days. KCl 3/32 M by itself is poisonous, killing the plants in thirty-two days. The addition of NaCl produces no more effect than in the case of Spirogyra.

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BOTANY
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CYTOLOGICAL STUDIES IN CYANOPHYCEAE

BY
NATHANIEL LYON GARDNER

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BOTANY

Vol. 2, No. 12, pp. 237-296, Pls. 21-26 November 10, 1906

CYTOLOGICAL STUDIES IN CYANOPHYCEAE

BY

NATHANIEL LYON GARDNER.

CONTENTS.

PAGE

I. Introduction and Technique 237
(a) Species Studied 239
(b) Collecting and Preparing Material 240
(c) Killing and Fixing Agents 245
(d) Stains and Staining 245
II. Recent Literature 249
III. The Cell Contents 259
(a) The Nucleus 260
(b) The Granules 269
(c) The Cytoplasm 273
IV. The Products of Assimilation 274
V. Experimental Cultures 275
VI. The Relation of Cyanophyceae to Bacteria 278
VII. Results 280
VIII. Summary 281
IX. Bibliography 283
X. Explanation of Plates 286

I. INTRODUCTION AND TECHNIQUE.

The somewhat aberrant group of plants known as the Cyanophyceae possesses many exceedingly interesting features, whether considered from a systematic, a physiological, or a cytological standpoint. These plants are representatives of a very ancient group which has adapted itself to the most diverse habitats while retaining its original simplicity of structure. They abound in the cold waters of the north, in the hot springs of the Yellowstone, of New Zealand, and of other parts of the world, where the temperature of the water is near the boiling-point; they grow in shaded places and in the open glare of the sun; are encrusted by

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lime on dripping rocks, penetrate into the shells of various mollusks, thrive equally well in fresh or in salt water, even when the latter is concentrated; in fact there is scarcely a habitat in which they may not be found, where any other forms of chlorophyll-bearing plants can exist. They even possess the power to withstand sudden changes in the environment. *Lyngbyas* growing in salt water may be placed in fresh water without affecting their growth, and will live for a long time if placed in distilled water.

The phylogeny of this group has not been well worked out. It is at present set off by itself with doubtful affinities, but the very fact of its diversity of forms suggests several lines of descent. Considered from the standpoint of external vegetative characters, it approaches somewhat the Chlorophyceae at several points. Some unicellular species of Cyanophyceae very closely resemble some of the unicellular Chlorophyceae. The same is true of some of the filamentous forms. And, finally, so closely do some of the membranaceous forms of the two groups approach each other, that one species (*Prasiola Gardneri* Collins) was placed in the Chlorophyceae until my cytological investigations showed that it belongs to the genus *Merismopedia* of the Cyanophyceae.

Interest is aroused in the cytologist by the group because in it he hopes to discover some clue to the origin of the cell-nucleus. A number of investigators of the group have turned their attention in this direction, and a variety of opinions has arisen concerning it. These cytological studies have also revealed the presence of a variety of structures in the protoplast upon which various interpretations have been placed. The questions of principal interest are: *First,* Is there a nucleus or not? *Second,* If there is a nucleus, what are its constituents, and what is its behavior during cell-division? *Third,* What is the structure of the cytoplasm? *Fourth,* Are chromatophores present or not? *Fifth,* What kind of granules are present, and what is their position in the cell, their structure, and their function?

The far-reaching importance of many of these questions, which are still in controversy, and the writer's especial interest in and familiarity with the group has led to the present cytological investigation.

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(*a*) SPECIES STUDIED.

The writer has been very fortunate in being located where such an abundance and variety of material may be found at all seasons of the year, having collected and studied over a hundred species in this vicinity. Many greenhouses, which are everywhere fertile sources for a number of species, are accessible. Many fresh-water springs and ponds, besides the salt marshes and the Pacific Ocean, teem with members of this group.

This abundance of living material at the writer's disposal all the year round has enabled him to make a free selection of the more typical members of each section of the group.

The principal species here studied are the following:—

Chroococcaceae.
- *Aphanothece sp.*
- *Synechocystis aquatilis* Sauvageau.
- *Synechococcus curtus* Setchell MS.
- *Merismopedia Gardneri* (Collins) Setchell.
- *Merismopedia glauca* (Ehrenberg) Nägeli.

Chamaesiphonaceae.
- *Dermocarpa fucicola* Saunders.
- *Dermocarpa prasina* (Reinsch) Bornet.

Heterocysteae.
- *Anabaena circinalis* Rabenh.
- *Anabaena Flos-aquae* Brebisson.
- *Anabaena Azollae* Strasburger.
- *Anabaena variabilis* Kützing.
- *Aphanizomenon Flos-aquae* Ralfs.
- *Cylindrospermum licheniforme* Kützing.
- *Cylindrospermum majus* Kützing.
- *Calothrix Braunii* B. & F.
- *Calothrix parietina* (Nägeli) Thuret.
- *Calothrix crustacea* Thuret.
- *Hassallia byssoidea* Hassall.
- *Nodularia armorica* Thuret.
- *Nodularia sphaerocarpa* B. & F.
- *Nostoc microscopicum* Carmichael.
- *Nostoc ellipsosporum* Rabenhorst.
- *Nostoc pruniforme* Agardh.
- *Scytonema Javanicum* Bornet.

Homocysteae.
- *Lyngbya Lagerheimii* Gomont.
- *Lyngbya aestuarii* Liebman.
- *Microcoleus chthonoplastes* Thuret.
- *Oscillatoria margaritifera* Kützing.

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Oscillatoria brevis Kützing.
Oscillatoria simplicissima Gomont.
Oscillatoria animalis Agardh.
Oscillatoria proboscidea Crouan.
Oscillatoria chalybea Mertens.
Oscillatoria sancta Kützing.
Oscillatoria limosa Agardh.
Oscillatoria tenuis Agardh.
Oscillatoria curviceps Agardh.
Oscillatoria splendida Greville.
Oscillatoria Bonnemaisonii Crouan.
Oscillatoria geminata Meneghini.
Oscillatoria amphibia Agardh.
Oscillatoria chlorina Kützing.
Oscillatoria laetevirens Crouan.
Oscillatoria acuminata Gomont.
Oscillatoria Okeni Agardh.
Phormidium uncinatum Gomont.
Phormidium favosum Gomont.
Phormidium submembranaceum Gomont.
Symploca Muscorum Gomont.
Spirulina subsalsa Œrsted.
Spirulina major Kützing.
Beggiatoa mirabilis Cohn.
Beggiatoa arachnoidea Rabenh.

(*b*) COLLECTING AND PREPARING MATERIAL.

The habitat of these plants is such that it is difficult to avoid getting sand and various kinds of debris along with almost every collection.

If microtome sections of these small plants are to be made, it is exceedingly desirable to have clean material to cut; and to obtain this is quite troublesome, in some cases almost impossible. This is particularly true of heterocysted forms like *Nostoc,* which imprison sand within the gelatinous thallus. The writer was confronted from the first with this difficulty, which necessitated the invention of some methods whereby suitable material might be procured. A few of these methods are given here.

If *Oscillatorias* and other actively crawling forms which contain sand and debris are to be used, the decantation method is found to be simple and practical. The whole mass is put into a tall jar and thoroughly shaken up, and then allowed to settle for a short time, after which the lighter floating material containing

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the plants is poured off. This process is repeated until the coarse, heavy material is removed. Graniteware pans have been found to be most convenient to hold the plants thus segregated, since they are opaque. This material is placed in the shade and allowed to settle to the bottom of the vessel, whereupon it will crawl to the center in a mass. Any fine debris remaining on the surface is disposed of by floating a sheet of paper on the surface and removing paper and debris together. When placed in direct sunlight oxygen is given off, and, collecting into bubbles, is held in the meshes of the trichomes, so that the whole mass of plants with some fine debris is raised to the surface of the water. From the margin of this mass the plants crawl out and form a thin, clean layer on the surface of the water. This thin, floating layer, which forms a fringe around the mass of material, is carefully trimmed away with a pair of sharp scissors, and placed in a vial with water. In order to get the filaments thus trimmed off into a small mass for embedding, they are repeatedly sucked into and forced out of a pipette until thoroughly broken up. On standing for a few hours in the shade, they will be found to have crawled together again into a single mass, and in this condition may be killed and embedded in paraffin for sectioning.

If an abundance of material is at hand, as compared with the amount of soil and debris, one may, instead of bringing it into the direct sunlight, allow it to remain in the shade on the bottom of the vessel until the plants have crawled out of and formed a thick layer on the debris, from which the clean top layers may be removed with fine forceps, if due care is exercised.

Some of the small species are found scattered among fine debris. In order to get them clean, centrifuging may be resorted to. This separates the debris and leaves the plants still scattered through the water, which may now be decanted and collected by filtration. The best filter paper I know of for this purpose is Schleicher & Schüll's No. 575. This is firm, smooth, and strong, and may be subjected to considerable force in a filter-pump. Chamois skin may also be used for this purpose. If desired, the material may now be taken out and killed, then washed by means of the above apparatus, preparatory to embedding. This is a practical way to wash any form, for it is otherwise difficult to

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prevent the loss of much of the material unless it adheres firmly in a mass.

After the material is washed, it may be placed directly in a dialyzer, and by this means slowly dehydrated, thus preventing shrinkage and also the loss of material.

The embedding and cutting of material is at best a slow process, requiring skill and patience to secure sections suitable for careful study. Experience has shown that many things may be learned about the cell by the use of other methods which facilitate the work and enable one to arrive at the same results in a much shorter time. In fact, it is only in exceptional cases that one needs microtome sections. So far I have been able to demonstrate everything which was revealed by the thin sections without resorting to cutting, and consequently use sections now only to supplement and check results obtained without it. Everything may be seen in the small plants, only a few microns thick, if properly stained.

It is also desirable to study the nucleus as a whole, in longitudinal view, and this has been found to be possible and practical in uncut cells.

Most of the forms have a sufficiently gelatinous wall to cause them to adhere to the slide without any assistance, and may be stained, washed, and permanently mounted within a few minutes, provided a study is to be made without previously killing them. If it is desired to kill them previous to staining, this may be done by placing the slide with the adhering material directly in the killing agent, after which it may be washed, stained, and treated as desired. The more they are handled, the more liable are the specimens to be lost, and if one has forms like *Oscillatoria,* which are not very gelatinous, it is well to place on the slide first a little albumen fixative. *Nostocs, Anabaenas,* etc., of the heterocysted group, do not require this, being sufficiently gelatinous to adhere firmly to the slide.

It is highly desirable to get the material spread out very thin on the slide, and a good method for doing this with the rapidly crawling forms is to allow them to spread out on the surface of the water, as mentioned above, trim off small pieces, which should be carefully floated upon a slide (this may be previously smeared

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with albumin fixative if desired), after which the superflous water is wiped off, and the remainder of the water allowed to evaporate almost to dryness, when the plants are ready for further treatment; or one may place the material, free from debris, in a large drop of water on the desired part of the slide, and allow the water to evaporate. In this condition the plants usually crawl out radially in a thin layer on the slide.

If gelatinous forms are being used, a very small quantity of clean material is placed on the slide and pressed gently with a cover glass into a thin layer, after which the cover should be slid off, not raised straight up.

After staining, the material need not (except in very few cases, *e.g.*, some of the large thin-walled *Oscillatorias*) be run up through the grades of alcohol, for shrinkage will not occur to any detrimental degree if 90 per cent., and then absolute alcohol be dropped on directly with a wash-bottle. For preliminary examination clove oil is best, for this clears the plants and takes out the water, and, if permanent mounts are desired, they can be transferred directly to balsam. Clove oil cannot always be used because some of the stains (*e.g.*, most of the violets) are so readily soluble in it. I have found, however, that in general the violets are not very useful, and, having found better stains, have almost abandoned their use.

End views of cells of the large species of *Oscillatorias* and some other genera are very desirable for getting at the structure of the nucleus. For this purpose a method has been worked out which is vastly superior to the embedding and sectioning method. This method consists in using a killing agent which will affect the cross-cell walls in such a way as to cause the cells to separate easily. In selecting such an agent it was necessary that one be found which would not cause the trichomes to shrink, and also one which could be followed by a variety of good differential stains.

Alcohol will serve this purpose in some of the thin-walled short-celled forms, but the cells do not separate so readily as is desirable, and a large number of them become broken and distorted. The material is killed in 95 per cent. alcohol for half an hour, after which the slides with the mounted plants are placed

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directly in water for a few minutes. On removing the slide and wiping off the superfluous water, a cover glass is placed over the material, and with slight pressure and with a rolling motion, the plants are broken apart and the cells fall down on their flat surfaces. The cover glass should be removed by sliding it to one side, and not by raising it straight up. This helps to spread the cells out in a thin layer, and assists in getting them to adhere to the slide. A little albumin fixative may first be placed on the slide.

Picric acid will bring about the same results as alcohol, and is a good killing agent, but has many disadvantages. Too much time is required to kill the plants, and then much more time is required to get rid of the acid. This is done by washing in alcohol, and care is necessary to prevent the shrinkage of material. Picric acid also has a tendency to loosen the plants from the slide, which then become lost in washing, and, further, it has the disadvantage of not being a killing agent that can be followed by the best differential nuclear stains.

The very best preparation I have thus far found for causing the cells to separate is a strong solution of iodine in strong aqueous solution of potassium iodide. This is an excellent killing agent, acting instantaneously, without shrinking the protoplast to any perceptible degree. Material is mounted on the slide as above described, and a drop of the solution placed upon it, or the whole slide placed in the solution for 10 to 30 minutes, though much longer time will not injure the plants. The material is now washed with 95 per cent. alcohol for about the same length of time, then placed in water for a few minutes, after which it is ready to be treated as above described. The cells break apart readily, adhere to the slide well, and on drying are left round and plump and ready for staining. All of the best differential stains which I have employed for both nucleus and granules may be used after this killing agent with excellent results.

This method is in many ways superior to the microtome sections. There is far less chance for misinterpretation of the shape and location of various cell-organs. One obtains by this method single cells free from other or parts of other cells, a thing which is practically impossible to obtain with microtome sections. Perplexity and confusion arise when one attempts to interpret parts of several or even of two cells in an oblique section.

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The cells of the Principes and Margaritiferae groups of *Oscillatoria* are sufficiently short to allow one to see everything perfectly in properly stained isolated cells.

If one wishes paraffin sections of plants belonging to other genera, it is expedient to use potassium iodide-iodine as a killing agent, for washing and dehydration can be accomplished at the same time. Plants killed in this way can usually withstand being dehydrated rapidly without shrinking.

(*c*) KILLING AND FIXING AGENTS.

Besides the killing agents just mentioned, *viz.*, alcohol, picric acid, and potassium iodide-iodine, the following were tried:—

Flemming's weak and strong chrom-osmic-acetic solutions, saturated aqueous solution of corrosive sublimate, 1 per cent. chromic acid, Hermann's mixture, and iridium chloride.

Potassium iodide-iodine seems to be perfectly satisfactory, hence experimentation with many other solutions has not been resorted to. Flemming's solutions are almost as good as the iodine in the majority of cases, but do not have the advantage of being so easily washed out, and do not dissolve the cross-walls.

(*d*) STAINS AND STAINING.

At the beginning of this investigation two points of technique were specially considered. First, the best killing agents that would produce practically uniform results when followed by a variety of stains; and second, the best differential stains that would uniformly reveal homologous structures in a large enough series of plants to form a basis for the interpretation of the cell structure.

Throughout the work, a Zeiss instrument, with Abbé condenser, 2 mm. apochromatic objective, and 8, 12, and 18 compensating oculars has been used. A white light has been secured by means of a special lamp, and, after being condensed by a large globe of distilled water, has been modified at will by variously colored glass disks.

The following stains have been employed. They are all Grübler's except those marked otherwise.

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LIST OF STAINS.

RED AND ORANGE STAINS.

Bordeaux red.
congo red.
ruthenium red.
neutral red.
rubin G., Bausch & Lomb.
rubin S.
erythrosin.
eosin.
carmine, aqueous.
Schneider's aceto-carmine.
Hoyer's picro-carmine.
Woodward's carmire.
Heidenhain's iron haematoxylin.
Ehrlich's haematoxylin.
Böhmer's haematoxylin.
Delafield's haematoxylin.
Mayer's acid haemalum.
fuchsin, aqueous, and alcoholic.
Ziel's carbol fuchsin.
safranin.
sudan III.
orseille G., Bausch & Lomb.
peruvin.
orange G.

GREEN STAINS.

iodine green.
solid green.
light green.
aniline green.
coerulein S.

BLUE STAINS.

toluidin blue, Chas. C. Riedy, S. F.
china blue.
wasserblau.
victoriablau.
methyl blue.
methylene blue, aqueous.
Loeffler's methylene blue.
blue de Lyon.
thionin, Queen & Co., Phila.
cyanin.
aniline blue.
blue lumiere, Chas. C. Riedy, S. F.
alizarinblau.

BROWN AND BLACK STAINS.

Bismarck brown.
schwarzbraun.
wollschwarz, Chas. C. Riedy, S. F.
nuclear black.

VIOLET STAINS.

crystal violet.
methyl violet.
Hofmann's violet.
säure violet.
gentian violet.
methyl violet 6 B.
methyl violet 5 B.
dahlia.

The method of attacking the problem was first to select from the abundance of material a species with well defined cell-organs to use as a basis of comparison, and also to serve for testing the action of various killing agents and stains. The nucleus was selected as the first object for demonstration, and for this purpose study was begun on the living plant. After careful investigation to ascertain what could be seen by the aid of the highest magnification of the microscope, stains were run under the cover glass

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and their action on the living material noted. Loeffler's methylene blue was used first, and it was soon discovered that while not all the Cyanophyceae cells are alike in cytological characters, one feature of their reaction to stains seems to be common to all, *viz.*, that the central part of the cell uniformly has a stronger affinity for stain than other parts. The central part in many species will be intensely colored even before the cytoplasm through which the stain has to pass is colored. Most specific chromatin stains act in the same way. This leads to the belief that chromatin may be present in this part of the cell. But by this method alone differentiation is not sufficient to enable one to determine the form in which it exists, for very soon other cell-organs become colored, and the whole protoplast becomes diffusely stained. The method afterward employed was to "overstain," and then to remove the superfluous stain and dissolve out that which seems to be held mechanically or in loose combination, observing which parts of the cell give it up first. It was found by this method that the central part of the cell is uniformly the most tenacious of chromatin stains. It was further found that the central part is not homogeneous. The whole mass does not equally become fainter as the stain disappears, but certain parts resist the action of the solvent a long time. In most species thus stained it was found that the granules were the last to give up the stain. Much variation exists among the species as to the degree of differentiation of the central part, and it was not a simple matter to determine at first what is typical. Pursuing the method of staining *intra vitam*, I finally came across *Symploca Muscorum*, which, although having quite a thick sheath, has a very strong affinity for aqueous methylene blue; and in this, as in other species, the central part takes the stain first. Furthermore, the action is almost instantaneous. Staining on the slide with aqueous methylene blue, dehydrating, and mounting in balsam may be accomplished within 5 minutes, with a most excellent differentiation of the central part of the cell. The granules stain red and are scattered within and around the mass of branched thread-like structures which stain blue, while the surrounding cytoplasm remains bluish or greenish, according to the degree of washing out of the stain. In this species was found something

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sharply defined upon which to work, and it was selected as a representative form for a complete and careful study, after which it was used as a basis for comparison with similar structures in other plants. First a number of standard aqueous nuclear stains were used upon the living material. The plants were washed in alcohol and examined in clove oil (just as when stained with methylene blue), with the result that the same structures uniformly appeared. Among the stains used were ruthenium red, neutral red, rubin G., safranin, toluidin blue, china blue, and thionin; and of these the best in general were found to be the blue stains, since they act like double stains, coloring the granules red, thus differentiating them from the other structures, all of which stain blue or bluish. The red stains do not so clearly separate the granules from the thread-like structure in the center of the cell.

To supplement and check this work, plants were killed with several different killing agents, *e.g.*, alcohol, Flemming's solutions, 1 per cent. chromic acid, and potassium iodide-iodine, after which the stains mentioned were applied. Without exception the same structures were revealed as before, but not equally well defined. Chromic acid and Flemming's solution followed by the blue stains do not yield so clear and definite results as these stains do on the living material, nor are the blue stains so good after these killing agents as the red stains. Material killed with potassium iodide-iodine or with alcohol stains about the same as the living material.

Corroborative evidence coming from such a variety of sources as we have here warrants the conclusion that the structures revealed by the methylene blue on the living material are real and not artifact. Furthermore, the selective action of these chromatin stains as indicated here is evidence that the thread-like structure is composed of chromatin.

If in all of the species of Cyanophyceae the chromatin were as easily differentiated as it is in *Symploca Muscorum*, little trouble would be involved in the interpretation of its behavior during cell division, but this is found not to be the case. The abundant granules in the center of the cells of some species, as well as granules embedded in the peripheral cytoplasm, have been a

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source of much confusion, and it was not until I was able to differentiate the granules and stain each kind separately without staining the chromatin, and further to stain the chromatin without staining the granules, that this source of error was removed.

The stains I found to be particularly troublesome in failing to differentiate granules from chromatin and in yielding uniform results on different species are Heidenhain's iron haematoxylin and Flemming's triple stain. Early in the work Ehrlich's haematoxylin was tried without good results, but the poor results were found later to be due to the condition of the stain, which was probably either "unripe" or "over ripe." Later some new Ehrlich's haematoxylin was made up, in which Grübler's haematin was used instead of haematoxylin. The mixture was placed in the sunlight and occasionally shaken for a few days, until the haematin and alum were mostly dissolved.

This stain was found to be the very best differential chromatin stain of the entire series used. It has the advantage of being an excellent killing agent, so that the living material mounted on the slide may be killed and stained at the same time, and has the further advantage of differentiating well after a variety of killing agents. With this it is possible to stain the chromatin without staining any of the granules. To do this requires but a few minutes. If left in the stain longer, the central granules also absorb it and become even more deeply stained than the chromatin. Over-staining may be washed out with acidulated alcohol, 1 per cent. to 2 per cent. HCl in 95 per cent. alcohol.

II. RECENT LITERATURE.

That the structure of the Cyanophyceae cell has been exceedingly difficult to work out and to understand is evidenced by the fact that from the time the task was begun until the present there has been continuous disagreement concerning the nature of the various parts of the protoplast.

It is not the purpose of the writer to go extensively into the literature on the subject in this brief paper. Several good reviews have been published from time to time, among which are

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those by Fischer, Kohl, Macallum, Phillips, and finally Olive's ingenious tabulation of opinions. It is thought expedient, however, to say a few words concerning the nature of the problems, and particularly concerning the recent efforts toward their solution.

Since the nucleus in the higher organisms is looked upon as the governing center of cell activity, the demonstration of the presence or absence of such an organ in the Cyanophyceae cell was naturally one of the first things to claim the attention of the cytologist. The first paper to appear on the subject was by Schmitz in 1879. He decided that the Cyanophyceae cell has a nucleus, but the next year after further investigation he changed his mind. Of the thirty or more writers on the subject, about one-half share Schmitz's final opinion.

The question of interest and importance which naturally follows the demonstration of a cell nucleus is the interpretation of its behavior during cell division. Of the workers who find a nucleus in the Cyanophyceae about one-half claim that its division is mitotic, and the other half that it is amitotic. Thus we have a series of views on this subject ranging from that of Schmitz, who claims that there is no nucleus, to Lawson, who sees a primitive nucleus, and Wager, who sees a nucleus with amitotic division, and finally to the other extreme held by Kohl and several others, who find a nucleus with mitotic division. No less confusion prevails among workers respecting other cell-organs.

Three papers have recently appeared describing mitosis in the Cyanophyceae, but their descriptions signally fail to agree, even when relating to the same species. They are by Kohl, Phillips, and Olive.

Kohl worked upon *Tolypothrix lanata* Wartmann, *Nostoc caeruleum* Lyngbye, *Anabaena catenula* B. & F., *Oscillatoria limosa* Ag., and *Oscillatoria splendida* Greville. His preparations revealed to him the presence of a nucleus without a nuclear membrane, and further that the nucleus divides mitotically. He divides this mitotic process into six stages, *viz.*, first, the formation of a spireme; second, the breaking of this spireme into a definite number of chromosomes, which arrange themselves parallel to the long axis of the cell; third, the constriction of the mitotic figure

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in the middle into the shape of an hour-glass; fourth, the "diaster" stage, in which the chromosomes are divided in the middle into two groups which move apart, and in favorable cases, spindle fibers are seen in the center of the figure; fifth, the daughter chromosomes arrange themselves parallel to each other and to the long axis of the cell; and sixth, the union of the daughter chromosomes into a daughter spireme.

To place before the reader the views of Phillips, I quote from his summary of results:—

1. "The central body of the Cyanophyceae is composed of chromatin and is a true cell nucleus."

2. "This nucleus divides by one of two methods, both of which start upon the karyokinetic history, one going no farther than the net-spireme stage, where it constricts itself into halves, while the other continues farther and forms a rudimentary spindle with rudimentary chromosomes upon linin threads.

4. "The chromatin is arranged on the spireme thread in granules which multiply in number by transverse divisions.

5. "There is no longitudinal splitting of the chromosomes or of the spireme, and in the division of the cell by the method first mentioned above, the two portions of the nucleus are not necessarily equal.

6. "The chromatin is aggregated in hollow vesicles in the resting cell. These vesicles give out their chromatin to the net-spireme very much like the nucleoli of the higher plants, and they may represent it. They are embedded in a granular ground substance.

7. "The cyanophycin granules and slime balls are probably food products. They are located in the chromatophore."

Phillips worked upon "*Nostoc* (three species), *Nostoc* in *Collema, Gloeocapsa polydermatica, Oscillatoria imperator, O. Froelichii, O. nigra, Cylindrospermum macrospermum, Spermosira litorea, Anabaena flos-aquae, Tolypothrix lanata, Rivularia pisum, Gloeotrichia,* and *Spirulina.*"

According to Olive (who has worked upon *Phormidium, Oscillatoria, Nostoc, Cylindrospermum, Calothrix,* and *Gloeocapsa*), there is a nucleus which divides mitotically. He finds "a more or less dense, fibrous, achromatic portion, and, enclosed by this,

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a number of minute, globular or somewhat irregularly shaped chromatin granules." He states that both these substances stain with the "standard nuclear stains, *e.g.*, iron haematoxylin and Flemming's triple stain." During mitosis all the characteristic structures are present, including spindle fibers. The chromosomes, which are constant in number for each species, divide crosswise in mitosis.

To explain his interpretation of the spindle and its origin, I quote his sixth conclusion, p. 36: "The kinoplasmic achromatic portion of the central body constitutes a spindle, which has the shape of a flattened disc in the narrow celled species; and in the longer celled forms, of a broad-poled, somewhat cylindrical figure; or in still others, narrow-poled and spindle-formed. The achromatin consists of a central spindle, which is often very densely fibrous, between the dividing chromosomes, and a portion leading from the chromosomes to the cross-walls, which corresponds to the mantle fibers in position and apparently in function."

Conclusion seven reads as follows: "A spireme arrangement of the chromatin granules is also evident in the preliminary nuclear changes. The segmented spireme in *Gloeocapsa* appears to consist of a simple, more or less spiral thread, having about eight chromatin granules held by the linin, and situated in the middle of the cell, with its long axis corresponding to the long axis of the cell."

"In the filamentous species the spireme apparently consists of a much convoluted thread, and it is further probable that it also is made up of a definite number of distinct chromatin granules, arranged along a linin thread."

From conclusion nine I quote the following concerning the number of chromosomes:—

"The number of chromosomes in the cells of the same species is constant. . . . Each chromosome apparently corresponds to a simple chromatin granule of the spireme thread. Should this prove to be true, then this presents the hitherto unrecorded phenomenon of a chromosome which consists of a single chromomere."

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Relative to the splitting of the chromosomes, his eighth conclusion reads: "Finally, the most necessary requirement of mitosis is fulfilled in that a longitudinal fission of the chromosomes occurs. This is plainly evident in the case of *Gloeocapsa,* in which the simple spireme threads divide lengthwise, beginning at the two ends and splitting thence progressively to the middle of the thread. It is highly probable, further, that the splitting of the convoluted spireme of the filamentous species takes place in a somewhat similar manner, since the fission plane begins at the edge of the disc-shaped figure and travels progressively inward to the middle."

Finally I wish to quote his eleventh conclusion concerning the continuity of mitotic activity.

"Although the central body in vegetative filaments seems to be in a continuous state of mitotic activity, it appears occasionally to make a beginning toward a resting condition and to form a delicate membrane and karyolymph. It is probable, however, that the nuclei in the active filaments do not ordinarily approach nearer to a state of rest than the spireme condition or a stage immediately prior to it."

From the foregoing it will be seen that these three authors all agree that there is a nucleus in the Cyanophyceae. They have all worked upon at least one species in common, *Oscillatoria limosa* Agardh (*O. Froelichii* Kützing), yet they have three different interpretations as to the manner in which this nucleus divides. Of these three, Olive seems to have found the greatest conformity in nearly all particulars to the various steps in the typical mitosis of a higher plant cell.

After very careful and prolonged investigation I am unable to subscribe to any of the conclusions just quoted concerning the mitosis of the nucleus in any of the Cyanophyceae upon which they have worked. I have carefully investigated *Oscillatoria limosa* and *O. splendida,* two species upon which Kohl worked, and can speak positively in regard to mitosis in these. There is in no portion of the life-history of the cell any configuration of the chromatin present that can be interpreted as belonging to a mitotic process. The process in the nuclei of these two plants is purely and simply amitotic. Kohl's conclusions are based pri-

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marily upon the nucleus of *Tolypothrix lanata,* but he says on p. 177: "Der Verlauf der mitotischen Kernteilung ist nun genau derselbe bei den beiden *Oscillatoria*-Arten wie bei *Tolypothrix.*"

Zacharias, who has done much work on the cytology of the Cyanophyceae, states that through the kindness of Dr. Kohl he has been permitted to examine these preparations, and after doing so, fails to agree with his conclusions. He remarks concerning these preparations that "Die stärker gefärbten, mannigfach gestalteten Teile der Zentralkörper, wie sie die Präparate und die Figuren der Autoren zeigen, halte ich nicht für chromosomen, sondern für (teilweise auch durch das Präparations-verfahren deformierte) Vorsprünge, Leisten, etc., der Zentralkörper."

Judging from preparations treated in like manner, I agree with Zacharias that these projections, etc., are not chromosomes as ordinarily understood.

Phillips has a more complicated scheme for mitosis than Kohl. In fact, he has two methods, both of which he says may occur in the same species. It would be exceedingly interesting to learn under what condition these two processes take place, and why one should occur at one time, and another at another time.

In either case, the resting condition of the cell is described as having the chromatin distributed within the nucleus in the form of hollow vesicles, and, when nuclear division begins, the first step is the transformation of these chromatin vesicles into a diffuse mass throughout the nucleus. This diffuse mass now collects into a network of threads along which, particularly at the junction of the threads, are arranged chromatin granules, which increase in number by division in a plane perpendicular to the thread. At this stage one of two things may happen. The network is either constricted in the middle into two parts after being drawn to the "equator of the cell," or it is resolved into a spireme thread. If the former case prevails, the two masses are drawn into the daughter cells and separated from each other by the ingrowing cross-wall. Of their subsequent history nothing is said.

If the other process prevails, after the orientation of the spireme in the direction of the long axis of the cell, it breaks up into a number of "segments" or "chromosomes." At this juncture

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the chromatin arrives at a place of variability. There are either several fine chromosomes, or the segments may consolidate into a few large chromosomes. The next step is the simultaneous cross-division of these parallel chromosomes in the middle. The cell-wall grows across and completes the division by cutting in two the "linin connectives," and forming the two daughter cells. The fate of the daughter chromosomes is here again uncertain. They are either resolved into a new network or changed back again to the chromatin vesicles.

It is to be noted in this scheme of mitosis that extreme variability prevails.

The karyokinetic process as described by Olive is here briefly outlined.

Chromatin granules are embedded in the achromatic substance of the never resting cell. These granules arrange themselves along a linin thread, which becomes the "segmented spireme" in *Gloeocapsa* or the "convoluted spireme" in the filamentous forms. The granules of which the spireme thread is composed constitute the chromosomes of which there is a definite number in the cell of each species. The next step after the formation of the spireme is its longitudinal splitting, thus accomplishing the equal division of all the hereditary qualities. The mantle fibers extending to the cross-walls attach themselves to each dividing daughter granule or chromosome, and the whole mass is pulled into the daughter cell, after which the remainder of cell division is accomplished by the ingrowing of the cell-wall, and separation of central spindle and cytoplasm. The daughter granules, or chromosomes, are still embedded within the achromatic substance, and a second division proceeds exactly as before. This second division may begin before the first one is completed, and even a third and a fourth division may be in progress before the original one is accomplished.

From these brief summaries it will be noticed that there are widely different views, not only as to the number of different steps involved in the mitotic process, but also as regards the essential manner in which these processes are carried out. A clearer comparative understanding of the three processes of mitosis just briefly outlined may be obtained from the following treatment of

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the subject in which the views on each structure and process are brought together.

All three workers agree in calling the "central body" a nucleus, and Kohl and Phillips agree that it may enter upon a state of rest, though Kohl thinks this is very rare, while Olive finds it in continuous mitotic activity, except in spores and heterocysts.

STRUCTURE OF THE NUCLEUS.

Kohl. The nucleus is composed of a ground substance, "Centralkörner," and chromatin.

Phillips. The "central body," the nucleus, is composed of chromatin (p. 325, first conclusion) and a "finely granular ground substance" (p. 284).

Olive. The "central body," the nucleus, "consists of a more or less dense, fibrous achromatic portion," and "a number of minute globular, or somewhat irregularly shaped chromatin granules" (p. 35), and sometimes central granules.

THE GROUND SUBSTANCE.

Kohl. The ground substance sends out radiating threads to the cell-wall.

Phillips. The granular ground substance permeates the nucleus and sends out finely granular kinoplasmic-like processes through the "chromatophore," which pass out to the cell-wall and form the central part of the "protoplasmic ciliary-like growths" (p. 284), and actually pierce the cell-wall, and "cause the movements of the trichomes" (p. 326).

Olive. The shape of the ground mass varies with the shape of the nucleus.

CHROMATIN.

All three agree that chromatin is present in the nucleus of the Cyanophyceae, but of the form it assumes and of its behavior the following is said:—

Kohl. "Wie jeder Zellkern, so enthält auch der Zentralkörper der *Cyanophyceen* Substanz, welche sich gewissen Färbungsmitteln gegenüber anders verhält, als die Grundmasse des Zentralkörpers. Da diese sich distinkt färbende Substanz sich

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ausnahmslos in den Gebilden wieder findet, die wir Kernfaden und Chromosomen nennen, so darf ich diese Substanz wohl als Chromatin bezeichnen" (p. 122).

Phillips. According to this author, the chromatin exists in the "central body," the nucleus, of the resting cell, in the form of "hollow vesicles" (p. 284). These hollow vesicles he identifies as being the same as the "slime balls" of other authors, and the "red granules" of Bütchli (p. 282).

Olive. Globular, or irregularly shaped, presumably solid granules (p. 35).

THE BEHAVIOR OF CHROMATIN AT THE BEGINNING OF CELL DIVISION.

Kohl. "Der dicke Kernfaden durchzieht in Windungen den Kern" (p. 173).

Phillips. The chromatin of the "vesicles" becomes diffused through the "central body," the nucleus, and then forms itself "into a more or less loose network" (p. 295); and "the chromatin is arranged on the spireme thread in granules" (p. 325, fourth conclusion).

Olive. The chromatin granules become embedded in a "segmented spireme" in *Gloeocapsa*, and in a "convoluted spireme" in other species.

SPIREME.

Kohl. The spireme is formed by the union of chromosomes from the preceding cell division, and is divided crosswise into a *definite* number of pieces, preparatory to a new cell division (p. 173).

Phillips. Two processes are possible with the "loose network." It is either directly constricted into two portions (p. 296), or it may form into "a single coiled linin thread or spireme," which breaks up into an *indefinite* number of pieces which arrange themselves parallel to each other and to the long axis of the cell (p. 296). Of the further history of the thread in the first process we have no record.

Olive. The spireme never breaks into chromosomes or segments. Each chromatin granule in the spireme is looked upon as constituting a "chromosome" which never loses its identity as such throughout the life history of the plant (p. 36).

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CHROMOSOMES.

Kohl. This author has a *definite* number of chromosomes in each species which, judging from his illustrations in tables *i* and *k*, separate simultaneously. The division is crosswise and in the middle (p. 173).

Phillips. An *indefinite* number of chromosomes is present, in some cases many fine ones, and in other cases about two coarse ones. In either case they divide crosswise in the middle simultaneously (p. 297).

Olive. A *definite* number of chromosomes is present in each species. These are divided in the same plane as the spireme in which they are enclosed or held fast, the division beginning at the ends of the "segmented spireme" in *Gloeocapsa*, and progressing toward the center, and beginning around the margin of the disc in the "convoluted spireme" of the short-celled form, progressing toward the center of the disc dividing the granules hit or miss as they are reached (p. 36).

SPINDLE.

Kohl. "Innerhalb der eingeschnürten Partie des Kernes konnte ich bei geeigneter Fixierung und Färbung deutlich Spindelfasern in wechselnder Zahl erkennen" (p. 173).

Phillips. An "open" spindle is formed by the segments of the spireme (pp. 296, 297).

Olive. The kinoplasmic achromatic portion of the central body constitutes a "spindle," the shape of which varies with the shape of the cell. It consists of two parts, one extending between the dividing chromosomes and the other attached to the chromosomes and extending to the cross-walls of the cell (p. 36).

NUCLEAR MEMBRANE.

Kohl and Phillips find no nuclear membrane, but Olive finds a delicate one in spores.

GRANULES.

Two kinds of granules have been observed by each of these writers, *viz.*, the "slime globules" and "cyanophycin granules."

From the doubtful manner in which some of these conclusions

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are expressed, and the appearance of the illustrations representing the material from which the conclusions were drawn, it seems that the existence of a karyokinetic process as here set forth is exceedingly doubtful.

From my experience in working on the same organisms it is manifest that the chief trouble which has confronted these investigators and obscured the truth, thus preventing a unanimous verdict, is the failure to discover a method which would clearly, definitely, and unmistakably differentiate the structures which are present. Because of this state of affairs, they have attempted to harness to a comparatively simple process of nuclear division the complicated mitotic process of the higher organisms, with its formation of spireme, chromosome, spindle, etc.

III. THE CELL CONTENTS.

The study of the protoplast of the Cyanophyceae cell has revealed to the writer the presence of the following structures, some of which are constant, while others may or may not be present, according to conditions which have not yet been definitely determined. First, there is a structure in the center of the cell which occupies a larger or smaller portion of the cell, according to the species; and its form is largely determined by the form of the cell. The degree of its demarcation from the surrounding elements is a variable factor. In *Oscillatoria margaritifera*, for example, the line of separation is not sharply defined, while in *Cylindrospermum* the line is as sharply defined as in some of the higher plants. On account of its appearance in the living cell, its reaction to stains and its chemical composition, I have decided to call this the cell-nucleus. Second, surrounding the nucleus and extending to the cell-wall is the cytoplasm, which varies in structure slightly in different species, as well as in the same species, according to the amount of the third kind of structure present, *viz.*, the granules. Incidentally, other structures have been noted in certain species, for example, more or less cylindrical refractive bodies in the cytoplasm of *Oscillatoria chalybea*, to which I have given no name nor ascribed any function. These do not occur in every collection of the species, but when present in a collection

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they are to be found in every plant. Since the other characters are constant in all collections, these bodies probably do not furnish a specific character, but only a physiological one. These are probably the refractive bodies spoken of by Gomont in his description of the species. Another constituent noted is the refractive substance connecting the heterocysts to vegetable cells, called "Verschlusskörper" by Kohl.

We will now take up the consideration of these various structures more in detail.

(*a*) THE NUCLEUS.

It has previously been mentioned that much controversy has already arisen among workers on the cytology of the Cyanophyceae over the question whether or not these organisms possess a nucleus. The answer to this question must necessarily depend upon the standard of judgment. If we use as a standard the well differentiated structure in the flowering plants known as the nucleus, with its well defined membrane separating it from the surrounding cytoplasm while in a resting condition, and with its intricate method of division, whereby its most highly organized substance, the chromatin, is handed down to the daughter nuclei in exactly equal quantities, then there is no nucleus in any one of the forms upon which I have thus far worked. This criterion, if rigidly held to, would eliminate a number of structures which have hitherto been considered as nuclei in the lower forms of life, and even in certain cells of highly organized animals and plants. But if it be conceded that these structures last referred to are nuclei, then there is a nucleus in the Cyanophyceae, clearly and unmistakably. The writer's conclusion is based upon the following evidence. First, the appearance of the nucleus in the living cell; second, its reaction to stains; and third, its chemical nature. There is present in the center of the cell of the Cyanophyceae a small refractive structure, well defined in some species and much less so in others, and quite constant in outline in a given species. In order to detect the presence of nuclei in doubtful cases and to make a more careful study of the parts and their behavior, staining is necessary. By this treatment it is found that certain parts,

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particularly during cell division, uniformly have a stronger avidity for stain than other parts, and that these parts have a definite procedure during every cell division. It has been found that iron and phosphorus are constant constituents of the nucleus. For the detection of these elements in the nucleus of the Cyanophyceae I have relied upon the careful investigation of Macallum, who has demonstrated the presence of both masked iron and organic phosphorus. These lines of evidences are corroborative. The refractive body is not a homogeneous mass, but contains a portion which has a strong affinity for "basic" stains, and contains masked iron and organic phosphorus. This structure is present as a constant organ in all living cells of the Cyanophyceae, divides at each cell division, and, so far as can be judged with present knowledge at hand, it performs all the functions of a cell-nucleus. In the mind of the writer this evidence seems ample to warrant its being called a nucleus, and it will be treated as such in the remainder of this account.

The nucleus of the Cyanophyceae cell contains, in all of the healthy vegetative cells of the forms studied, a ground mass, granules, and chromatin.

The ground mass of the nucleus has not been a subject of special investigation in this study, and the writer is not prepared to say much concerning the finer details of its structure and the part it plays in the life phenomena of the cell, but from what has been seen it seems to play no essential rôle in nuclear division except to act as a matrix in which the other parts are at all times embedded.

The granules vary in size and number. There may be one or more in each nucleus, according to the species and the conditions. Of this more will be said under the head of granules.

In any group of organisms in which there is a diversity of morphological differences such as exist in the Cyanophyceae, one would not expect to find the same nuclear differentiation throughout the group. The variety of nuclear forms found in the groups helps to confirm the universal belief in organic evolution, for among the various members of the group we find instead of a single pattern of nucleus a number of nuclear forms which may merge into each other, but which indicate divergence from a com-

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mon type. It is the belief of the writer that when all the species of the Cyanophyceae are investigated cytologically, a complete and intelligible series of nuclear differentiations with but few, if any, gaps will be discovered, beginning with a very simple form, and finally diverging into several types which will be found to join on to various species of Chlorophyceae by almost imperceptible degrees, thus closing up the gap which seems to exist between these two groups of plants.

While it is not the intention to attempt in this paper anything like a phylogenetic arrangement of the species of the group, a sufficient number and variety of forms have been worked upon to note the existence of at least three quite well defined types of nuclei. Furthermore, a sufficient number of forms have been worked out to warrant the conclusion that we have in this group of plants a series of nuclear modifications showing how the nucleus of the higher plants may have originated. These three types are based upon the degrees of differentiation of the chromatin, and its behavior during cell division. They are here designated as the Diffuse type, Net-karyosome type, and Primitive Mitosis type. The third type may be considered as having arisen from the first by a slight modification.

Judging from the species I have worked upon, and the morphological relation of these to other species in the group, the diffuse type seems to predominate, and probably represents the most primitive nucleus in the group. We will turn to its consideration first. This type is characterized by having the chromatin distributed throughout the nucleus in an indefinite way, in the form of thin plate-like or small angular pieces, or more or less branched and knotty thread-like masses, according to the species and to the shape and size of the cell in which it is located; or even a combination of these may be found in the same species. In whatever shape the chromatin is found, the essential characteristic is its quite equal distribution throughout the nucleus. It is to be found in the homocysted group, *e.g.*, in *Oscillatoria, Lyngbya, Phormidium, Symploca,* etc. Within this type may be found quite a continuous series, showing how a very primitive nucleus becomes modified by gradual steps in the direction of the nuclear structure found in the higher plants.

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The lines of modification are, first, the concentration of the whole nucleus toward the center of the cell and the consequent concentration of the chromatin; and, second, the union of the chromatin into a more or less continuous thread. The differentiation seems to be proceeding toward the spireme formation found in the dividing of the nucleus of the higher plants. Of all the species of Cyanophyceae thus far worked upon, Fig. 1 represents the type in its simplest form. In this species the nucleus occupies the larger part of the cell, and the chromatin is distributed throughout it in the form of disconnected irregular pieces. Fig. 2 represents a modification of this in the direction of the union of the chromatin into more of a continuous mass. Fig. 3 represents a modification in the concentration of the nucleus toward the center of the cell. In Fig. 4 we see both greater concentration of the nucleus and greater union of the chromatin. The nucleus in Fig. 5 represents about the extreme in both directions. It occupies a relatively small amount of space in the cell and is usually, though not always, united into a single mass, much branched, with free ends projecting. There may be smaller free masses in addition to the large mass, which is not solid throughout. Fig. 6 represents a nucleus with very irregular outline in which the chromatin is in the form of thin irregular plates, mostly united around the margin but discontinuous in the middle.

Longitudinal views of Figs. 1, 3, 4, and 5 are represented by Figs. 7A, 8, 10, and 9 respectively.

These figures are all of comparatively short-celled species; that is, relatively short as compared with the diameter of the trichome. The cell of Fig. 1 is about 30μ in diameter and the cells are from 3μ to 5μ long. In species whose cells are several times longer than broad the nucleus is extended in the longitudinal direction, and has a tendency to arrangement of the chromatin into the form of threads somewhat united, and these are oriented more or less parallel to each other, and parallel to the long axis of the cell. Figs. 12, 13, and 17 represent such an arrangement.

Figs. 11, 24, 25, and 26 represent a still higher degree of differentiation in the direction of a sharper separation of the cytoplasm and the nucleus. The chromatin is collected near the center

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of the nucleus into a few thread-like masses. In these respects it more nearly approaches the nucleus of higher plants than any other form studied. This is the only species of this genus which I was able to differentiate so sharply. Not every collection of this species showed the same structure. This indicates the breaking up of the type into several species, some of which are more highly differentiated than others. The measurements given for the species cover a greater range than one finds in a single collection. This case illustrates how some of the discrepancies may have arisen in the accounts of workers on the group.

The second type, the Net-karyosome type, is quite rare. I have come across but two well marked cases so far. These are found in the genus Dermocarpa, two species of which I have worked upon, *viz., D. fucicola* and *D. prasina*, the former of which is represented by Fig. 33. This type, with perhaps some modifications, will probably be found to be characteristic of all the forms of Chamaesiphonaceae, which reproduce in a similar manner to *Dermocarpa*. The type is characterized by having the chromatin united into a very definite fine network on which, particularly at the junction of the threads, are small granules or knots, presumably of chromatin, since they stain like the remainder of the thread. This whole network occupies a very large part of the cell, leaving only a narrow zone outside next to the cell-wall. Material of *Dermocarpa* killed in Flemming's mixture and sectioned does not differentiate satisfactorily with the nuclear stains. Aqueous methylene blue and Ehrlich's haematoxylin yielded fine results on material killed in potassium iodide-iodine.

The spores of *Cylindrospermum* have the chromatin arranged in very nearly the same manner as it is in *Dermocarpa*. I have not come across any forms yet in which there are granules on the thread, and the thread is not formed into quite so definite a network as in *Dermocarpa*. Figs. 19, 20, and 21 show the condition of the chromatin in the spore of *Cylindrospermum*. It seems that in the genus *Cylindrospermum* we have a transition between the first and second types, the nucleus in the vegetative cells on one side approaching the first type and on the other side that in the spores approaching the second type.

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Only a slight modification of the first type is necessary to produce the third or Primitive Mitosis type, which has been found in a single species only (Figs. 40–44). In this type the chromatin unites into a single contorted thread quite irregular and indefinite in shape. This thread breaks into a definite number of pieces preparatory to cell division.

The foregoing description of types of nuclei applies to the resting condition.

It seems appropriate here to say a few words about resting nuclei, since Kohl and Olive do not consider that the nucleus ever assumes that condition. I am not sure that I understand their point of view on this question, but if their meaning is a condition of the nucleus in which the chromatin is distributed through the nucleus in the form of fine granules when not dividing as is generally the case in higher organisms, then I can agree that the nucleus of the Cyanophyceae never reaches a resting condition. But if a resting condition in the ordinary sense is meant, in which there is no visible sign of any nuclear division or cell-wall formation, then the nucleus of the *Cyanophyceae* is as often in a resting condition as the nucleus of any other organism. Olive speaks of centers of activity of cell-division occurring with rhythmic regularity in the trichomes of filamentous forms. This would indicate that the cells between these centers of activity must be in a resting condition. Under ordinary circumstances almost any species shows from 30 per cent. to 40 per cent. of the cells in which there is absolutely no sign of cell-division or change in the shape of the nucleus to indicate preparation for division, and I have had cultures dry up slowly in which at least 90 per cent. of the cells were in a quiescent state. When cells are dividing rapidly the chromatin will be found in many cells to extend from cross-wall to cross-wall, while in the same collection, and even in the same plant, one may find the chromatin in other cells concentrated near the middle of the cell with a layer of protoplasm between it and the cross-wall. Many of the heterocysted group produce spores which rest for a time, often for months. The homocysted group produces hormogonia which act in the same manner. These are simply small groups of cells, from two to several, which survive when a filament breaks up from any cause.

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These, like the spores, rest for a time until favorable conditions arrive, such as proper temperature, moisture, food, etc., then they resume growth and build up new trichomes. During this time they must be quite at rest.

(*a*) THE DIVIDING NUCLEUS.

The division of the nucleus in the Diffuse type is unmistakably amitotic. Whether in the short-celled form represented by *Oscillatoria margaritifera* (Fig. 7) or in a long narrow-celled form represented by *Oscillatoria splendida* (Fig. 17), the process is very much the same and quite simple. The chromatin is distributed quite uniformly throughout the nucleus in the resting cell. It presents no peculiar characters or modifications in form or structure during cell division that do not exist in the resting cell with the exception in many cases of a constriction in the middle as if the ingrowing cell-wall were actually pressing the chromatin toward the center before dividing it. It is impossible to say at present what causes the chromatin to separate. The separation always takes place at the outer margins first and proceeds toward the center of the cell. In no case have I noticed the whole mass separating simultaneously. Whether the ingrowing cell-wall plays any rôle in the process or not, it is never very far from the edge of the divided chromatin. Fig. 7 represents cells in various stages of division: *a* represents a resting cell, *b* one in which the division has proceeded only a short distance, *c* one almost divided, and *d* a complete division. The chromatin in these cells is represented in greater abundance than exists in the greater number of cells in this species. An instructive series is shown in Fig. 12, in which *a* represents the first stage in the series. The only sign of division is the beginning of the laying down of the ring-shaped cross-wall. No evidences of nuclear division are yet manifest: *b* shows the wall grown into the chromatin which is beginning to separate; *c* represents a stage in which the entire mass of chromatin has separated except a single strand in the center. In Fig. 18 may also be seen the same condition of chromatin

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division and ingrowing cell-wall. These are not rare cases, but may be found in great abundance in any collection of actively growing plants.

The division of the nucleus in all the filamentous species studied, including both homocysted and heterocysted forms, is direct, or amitotic. I have never observed in any such species the breaking up of the chromatin into a definite or an indefinite number of chromosomes either in the form of rods or of granules. After cell division the chromatin in each daughter cell (practically one-half of the original amount in each cell) undergoes no essential change, retaining the same general structure as before division, and simply increasing in quantity; in many cases it does not wait to attain its normal size before beginning another or even two divisions. Although the chromatin of the spores of various heterocysted species unites into network in a similar manner as does that of the Net-karyosome type, its division is the same as that of the vegetative cells, that is amitotic. The whole mass of network is divided into two equal parts, the separation beginning at the margin and proceeding toward the center until the whole is divided. Fig. 20 represents a nucleus completely divided and the cell-wall grown across, dividing the original cell into two equal parts. Spore division does not always take place in this manner. Usually several divisions may be seen in progress at the same time.

The division of the nucleus in the Net-karyosome type may also be said to be amitotic. No spireme, spindle, or chromosome formation is present. We have in the species in which this form of nucleus is present a different procedure in division from that which is usually found in other organisms. The mature cell of the *Dermocarpa* may be several hundred times larger than the original young cell; at the same time there is but one mass of chromatin all united into a definite network, or in other words, a single very large nucleus. The chromatin in this large network breaks up simultaneously into a large number of small parts about equal in size. These become the centers of new cells which are now formed by the simultaneous laying down of new cell-walls around each mass of chromatin and its surrounding cell-substance. The mother cell-wall now ruptures and the whole

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mass of small cells floats out. These cells are known as conidia or schizospores. They are non-motile, and when they fall on a suitable substratum, usually on some living plant, they begin to grow and the chromatin mass increases in size, very soon forming another chromatin net as before.

Of all the forms of nucleus in the Cyanophyceae which I have investigated the Primitive Mitosis type as illustrated by *Synechocystis aquatilis* (Figs. 40–44) approaches nearest to the mitosis of the lower Chlorophyceae. The chromatin unites into a thread in preparation for cell division. This thread is not, however, a very definite one as regards its shape and disposition in the cell. The thread breaks crosswise into a definite number of segments, in this species three, which arrange themselves parallel to each other and to the long diameter of the cell. These break apart in the middle when the new cross-wall is to be laid down.

In this method of division, as in that of the first method mentioned, the cell-wall seems to push the segments toward the center in some cases and they are not always divided simultaneously. Fig. 43 illustrates this method. It should be said that the division of the chromatin thread seems to precede somewhat the ingrowing of the cell-wall, and the impression is not produced, as it is in *Oscillatoria,* that the ingrowing wall simply cuts the chromatin mass in two.

It will be seen from the foregoing methods of division of chromatin in the Cyanophyceae that there is not an exact division of the chromatin into equal parts, but only an approximation thereto, and further that there is no longitudinal splitting of the threads of the chromatin.

The formation of a constant number of chromosomes and the longitudinal splitting of the same in order to accomplish the exact partition of all of the chromatic elements, the bearers of the hereditary qualities, have constituted a working hypothesis upon which to explain inheritance. It is acknowledged that these plants have been handed down to us from very ancient times, and yet without this complicated karyokinetic process found in higher organisms they go on reproducing themselves in such fashion that each succeeding generation resembles the parent one as nearly as may be found elsewhere in the organic kingdom.

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(*b*) THE GRANULES.

The granular inclusions of the Cyanophyceae cell have occasioned much controversy. The questions of dispute have related to their number in a cell, their constancy, their location, their chemical composition, their function, and the number of kinds.

With the writer they have not been a subject of thorough investigation, yet some things have been quite definitely determined about them and these are recorded here. The investigation has led to the discovery of but two kinds of granules in the Cyanophyceae cell. These are doubtless the same that have been seen by many writers, but no attempt will be made here to try to harmonize the writer's discoveries with those of other workers, for it would probably only lead to further confusion of an already tangled subject. A number of different names have been employed to designate these various kinds of granules, some relating to their location, some to their reaction to stains, and some to their chemical composition and function. I am not at present prepared to say what terms should be used to designate these two sorts of structures which I have differentiated, and for convenience in this paper will employ the terms α and β for this purpose.

My conclusion that there are two kinds of granules present is based mainly upon their behavior toward stains. No chemical tests have been made. Results obtained by straining are at times deceptive, and should be supplemented by other methods. In the study of the granules the writer proceeded in a similar manner as in the study of the nucleus, finding out as much as possible with the living material, then by the application of concentrated aqueous stains to the living material. About all one can discover in the living material is that in certain species granules are present and some of them are arranged in quite a definite way, *e.g.*, along the cross-walls. In other species granules may be seen in the center of the cell, but in neither of these cases can one always see them in these locations, and further, if a species has them located in both positions, one is not able to say where the dividing line is, since they look very much alike in the living cell. To segregate them it was necessary to employ some stain that would

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stain one kind and not the other; and equally important, one that would not stain the other cell structures to obscure the granules. Two stains were found that will do this unerringly in all the species worked upon. These are Bismarck brown and wasserblau.

One kind of granules, which for convenience will be called α, are located within the nucleus in every healthy living cell of each species studied, with perhaps a few exceptions among the unicellular forms and in the genus *Merismopedia* (which were investigated at the beginning before proper technique was employed, and which I have not since been able to obtain). There is another exception which I have not yet been able to explain satisfactorily, *viz.*, mature spores.

The location of these granules is variable and depends upon the shape and size of the cell and also upon the structure of the nucleus. They are always in close proximity to the chromatin, but not imbedded in it, even in small filamentous species where the chromatin is often in a single irregularly shaped mass (Fig. 38). In the large species of *Oscillatoria* and other large filamentous forms they are scattered promiscuously through the nucleus among the chromatin elements.

The number of these granules is also variable in the same species at different times and in different species. The variation is probably due to differences in cell activity. In resting cells there is a tendency toward a constant number. At least this seems to be the case in small-celled species in which one can easily count them. There are often filaments of *Lyngbya Lagerheimii* (Fig. 38) in which there is but a single large granule close to the chromatin mass in each cell throughout almost the entire filament. These α granules occur sometimes with such regularity as to lead one to suppose them to be nucleoli, but they do not behave like nucleoli of higher plants, which tend to disappear during cell division. On the contrary, they seem to increase in number when the cells are actively dividing.

The exception above spoken of, *i.e.*, that they do not occur in the spores, seems significant. This was a difficult point to determine since the spores are not easy to stain on account of their thick walls, yet some stains were found which penetrate the wall.

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Ehrlich's haematoxylin is excellent for this purpose, since it does not stain anything deeply except the granules (when they are present in the young spores) and the chromatin. It has been found by the use of this stain that these granules disappear before the spore reaches maturity. They do not disappear at once, but become gradually smaller and finally disappear entirely. These granules arise *de novo* in the cell, and are not handed down by division and subsequent growth. It so happens, however, that if there are but a few in a cell they are so oriented that some will get into each daughter cell, for no healthy vegetative cell is without them.

I have at times seen appearances which indicate that the *a* granules divide, but the evidence is not sufficient and conclusive. There often appears to be a connection between two granules, but I presume that this is simply the deeply stained protoplasm the color of which is not washed out. The new granules usually arise in close proximity to the older ones. One may often see a series of several sizes together ranging quite gradually from largest to smallest. *Cylindrospermum* is an excellent genus in which to study them in the vegetative cells, and *Anabaena variabilis* furnishes a good example of their disappearance during spore formation, for here the spores mature gradually in a series.

Many of the granules appear hollow, or at least only the outer rim stains. These are usually the larger ones, the smaller ones appearing to be solid. The stain which I have so far found to be unerring in differentiating them is a saturated aqueous solution of Bismarck brown used on living material. This makes it exceedingly quick and simple to examine a species to detect if they are present or absent. Living material mounted on the slide as previously described may be stained, dehydrated and mounted in balsam within a short time, varying from a few minutes to half an hour, according to the species, but there is scarcely ever any danger of over-staining. The granules of material killed in potassium iodide-iodine or in alcohol stain equally as well with Bismarck brown as the living material. In some species the granules may become swollen when stained. Besides Bismarck brown, there are other stains which will stain equally well and differentiate these granules in some species. Methylene blue in aqueous

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solution on the living material is very fine for this purpose, but in many species there are too many other things stained at the same time for one to identify these granules positively. Usually the chromatin is stained blue and the granules red with this stain. An aqueous solution of thionin is also very satisfactory for staining the α granules. It is necessary to over-stain and then wash out with acidulated alcohol. The granules will be the last to disappear and these will be stained red. Fig. 14 represents a cell of *Oscillatoria margaritifera*, killed in potassium iodide-iodine and treated as above described.

The other, or β granules, are readily demonstrated with aqueous solution of wasserblau. The cytoplasm will also take up the stain and obscure the granules, so in order to differentiate them it is necessary to over-stain and wash out with acidulated alcohol, since alcohol alone will not sufficiently dissolve the stain to reveal them. They will be the last to disappear and will stain deep blue. Eosin and picrocarmine will also stain them, but not so satisfactorily.

Unlike the α granules (which are always present), the β granules may be or may not be present in a given species, although in some species they are quite constant. In some collections all of the plants will possess them, in others only certain plants, and still others only certain cells in a filament. Their presence seems to be due to physiological conditions, and in certain cases they seem to have quite a definite relation to the α granules. Thus in a spore formation in the heterocysted group, as the α granules disappear the β granules increase in number and size. There are indications of this phenomenon in the homocysted group. The β granules seem to increase as the plants go into a resting condition and the α granules seem to diminish. However, my observations on this last point are not sufficient to form a basis for judgment in the matter, but in the case of the spores it is true that the β granules increase greatly in number and somewhat in size (at times almost completely filling up the spore), while the α granules disappear entirely. The α granules probably give up their material either to form chromatin or to form the β granules, and the former is more likely since they are

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so closely united to the chromatin, while the β granules are probably accumulated food material.

In the homocysteae the β granules are located most frequently along the cross-cell walls, the location, however, being a specific character. In some species they are distributed quite evenly throughout the cytoplasm, and in a single instance (*Symploca Muscorum,* Fig. 13) they are scattered among the α granules in the nucleus, at least wasserblau which invariably differentiates them in other species stains some granules blue within the nucleus.

They arise *de novo.* Their development may be watched in *Lyngbya aestuarii* (Fig. 35), in which they are arranged along the cross-walls only. As the new wall grows in from the side, soon the β granules appear. They increase in size and number as the cell grows older. Fig. 39 represents their arrangement and occurrence in *Oscillatoria splendida.* Fig. 15 represents them in end view of *Oscillatoria margaritifera* stained with wasserblau, and Fig. 14 represents the first species first stained with thionin, then counterstained with wasserblau. The α granules are red and the β granules are blue. They are both represented in the same plane, but the α granules are, in end view, below the β granules; that is, they are within the nucleus while the β granules are along close to the cross-cell wall. This same differentiation is shown in Fig. 13, in which case the α granules are stained red with Ehrlich's haematoxylin.

(*c*) THE CYTOPLASM.

The space between the nucleus and the cell-wall is occupied by the cytoplasm, the structure of which, as would be expected, varies considerably in its finer details in different species, and also in different cells of the same species.

Much controversy has arisen over the shape of the achromatic portion of the nucleus. Under a certain treatment in some species it seems to extend as a distinct substance out into the general cytoplasm by means of fine radiating arms. My investigation has not yet been conclusive on this point. The stains which best differentiate the chromatin do not differentiate the achromatic por-

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tion distinctly, and no counterstain has yet been found that will do this, so I withhold judgment on this point at present.

In young cells, and in species in which no β granules are present, the cytoplasm, when killed with Flemming's solution and stained with Heidenhain's iron haematoxylin, is shown to consist of a regular network of delicate threads. In other species in which there is an abundance of β granules present, under the above treatment the cytoplasm has the appearance of a definite alveolar structure, because the granules do not stain with the haematoxylin.

There is usually a thin layer next to the cell-wall which in all cases is much finer in structure than the coarser structure toward the center. Figs. 1 to 6 inclusive show the protoplasmic structure in a plane in which no granules are present.

I have not been able to demonstrate protoplasmic continuity as seen by other workers. I have tried a large series of distinctively plasma stains for this purpose without meeting with success. Ziel's carbol fuchsin is a very energetic and selective stain, and leaves the cell-wall transparent, while the cytoplasm is deeply stained; yet in no species studied, from the smallest to the largest, have I been able to detect any connective strands of cytoplasm between the cells except in case of dividing cells, in which the ingrowing cross-walls have not yet completely separated the cells.

The connection between the heterocyst and the vegetative cell or spore may easily be demonstrated with aqueous solution of wasserblau on living material, washed out with acidulated alcohol after over-staining.

The cytoplasm contains the coloring matters, there being no special differentiation of chromatophore for this purpose.

IV. THE PRODUCTS OF ASSIMILATION.

A few tests were made to ascertain what are the products of assimilation. Starch has not been found in any of the species studied. Some authorities state that glycogen is a constant constituent of the Cyanophyceae cell as the first product of assimilation, while others affirm that it is never present in these plants.

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The ordinary microchemical tests did not yield definite and conclusive results to the writer. In order to test the matter further, the method of extracting glycogen from animal tissue was resorted to. Mercuric chloride and Esbach's reagent were used to precipitate proteids in macerated rabbit's liver, after which the glycogen was precipitated with alcohol. This was done to test the reagents and to secure glycogen for comparison. A quantity of *Oscillatoria* was then rubbed up in the same way with some of these same solutions, and filtered. The filtrate was then treated with alcohol, and a precipitate was thrown down which had the same appearance as the glycogen prepared from the rabbit's liver, and which gave all of the characteristic glycogen reactions. From this result it seems just to conclude that glycogen is produced in the Cyanophyceae.

Before making this test for glycogen, I was of the opinion that it is not to be found in this group of organisms, but that sugar is the first product of assimilation, and that the excess is stored in this form. I came to this conclusion because aqueous extracts of a variety of forms of Cyanophyceae pulverized with fine sand in a mortar always readily reduced Fehling's solution.

It is of course possible that this reducing body is something else than sugar; but, since glycogen is produced in the animal body from sugar, it is quite probable that the first product of assimilation in the Cyanophyceae is sugar, and that some of this is converted into glycogen and stored in this form.

V. EXPERIMENTAL CULTURES.

I have already mentioned that the Cyanophyceae as a group have persisted doubtless from very ancient time, because of their power of adaptability to changes of environment without much modification in form. There is scarcely a habitat to which some species has not adapted itself, and in many cases the same species is capable of withstanding extremes in heat, moisture, and air supply.

Several writers on the group have stated that change in habitat, even though slight, results in profound changes in cytological characters. The writer has made some observations and per-

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formed some experiments with the view of ascertaining if possible the nature of these changes. The effect of being subjected to long drought was first studied. A collection of *Phormidium uncinatum* was made after it had been dry for five months. The material was wetted and examined in this condition; afterward the aid of stains and fixing agents was resorted to. The results showed that what I have since proved by experimentation, *viz.*, that a large percentage of the cells were in a resting condition brought about by slow desiccation. A large number of hormogonia had been formed, and these began to grow very rapidly, soon crawling out of their sheaths. After a few days, more of the material was stained, and the only change that had taken place was the appearance of rapidly dividing cells. The chromatin, instead of being drawn into the center of the cell, in many cases now extended through a series of partially divided cells, or, in case of a recently divided cell, it was still found close to the cross-wall. So this sudden change from an aerial dry condition in the direct sunlight (in which it had persisted for months) to submergence in water and diffused light does not produce any perceptible change in the structure of the cell contents nor in the character of their reaction to stains.

Still further to test the effect of change from an aerial to an aqueous medium, living material of *Oscillatoria sancta,* found actively growing on soil in a greenhouse, was placed in water. In this instance there was not only a change from an aerial to an aqueous environment, but also a sudden change in temperature. The growth of the plants was not interfered with to a noticeable degree, and the cytological characters remained unaltered. The normal habitat of this species is of course not in a greenhouse, but outside, where it is subjected to variation of light, heat, and moisture. The same structure of the cell appears when these plants from a normal habitat are stained.

Symploca Muscorum withstood being dried up several times without manifesting any cytological modifications. A change in habit of growth occurs when this species is changed from an aerial to an aqueous environment. In the air the filaments unite into fascicles, somewhat cone-shaped, but in water they spread out.

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The effect of changing the concentration of the liquid medium was tried. *Lyngbya aestuarii* growing in salt water was transferred from this into fresh water, also into distilled water. Material was studied before and after the change, and on comparison the structure of the protoplast presented no unusual modification. This species will survive the change from salt to fresh water for many months, and even a surprisingly long time when changed to distilled water.

The rate of growth may be influenced in various ways. Other things being equal, the amount of light is a prominent factor in influencing cell division. If young, actively growing material be placed in the dark, growth proceeds very slowly, and after a few days or weeks, depending upon the species, will discontinue almost entirely. In diffused light growth proceeds more rapidly than in the dark, and in direct sunlight the maximum growth takes place. This is doubtless due in a large measure to nutrition rather than to the direct action of light rays. As a continuous habitat, however, some species prefer diffused light rather than direct sunlight. The comparative activity of cultures placed in direct sunlight and of those placed in diffused light or in the dark may usually be detected within a few minutes. Those placed in direct sunlight will be seen to be giving off more oxygen than the others. This collects and forms bubbles, which become entangled and held fast in the mass of filaments, in many cases soon buoying them up to the surface of the water. This has already been alluded to under methods of obtaining clean material. The metabolism of those in diffused light or in darkness is usually not sufficiently rapid to cause the accumulation of gas, which is absorbed by the water as fast as given off.

It is quite remarkable how tenacious of life some forms are when placed in the dark. A culture of *Aphanothece* which was in fair vegetative condition was placed in a dark chamber and supplied with enough water to keep it moist for sixty days. It then dried up and remained dry and brittle for fifteen more days. It was again wetted and some of the material stained, when it was found that a few cells were still dividing and that very few had died. The nucleus had become somewhat more concentrated into the center of the cell, and there were fewer gran-

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ules. The color was more of a "grass green" than a "blue green," which seems to indicate that the phycocyanin is first used up or disappears first under these conditions. This same material was then placed in the light and kept moist. It assumed its original color again, and grew for three months afterward.

To induce a resting condition in the cell, I have succeeded best by placing healthy material on compact wet earth and covering the vessel in which it was placed with glass in such a way as to allow evaporation to take place slowly until the material was completely dry and brittle. On wetting this material again and applying stains, it was found that at least 90 per cent. of the cells were in a resting condition, and that the nuclei were a little more concentrated in the center of the cell than they were in the actively growing plants, although otherwise the cell organs appeared to be the same as before.

VI. THE RELATION OF CYANOPHYCEAE TO BACTERIA.

The relation of the Cyanophyceae to the Bacteria, particularly to the sulphur bacteria, has been a subject of research by a number of investigators. Among those who have given special attention to the cytology of these organisms are Bütschli, Fischer, and Macallum.

In *Beggiatoa,* Bütschli was able to demonstrate a deeply staining part in the center of the cell and a lighter staining peripheral portion. In *B. alba* this peripheral portion he found to be very narrow. He looks upon the central portion as the analogue of a nucleus. Fischer and Macallum did not succeed in bringing out this differentiation. Macallum demonstrated the presence of "masked" iron and organic phosphorus uniformly distributed throughout the protoplast of *B. alba* and *B. mirabilis.*

The writer has given but little attention to these organisms, having worked upon but a few forms of the sulphur bacteria, chiefly of the genus *Beggiatoa.* These forms are usually so filled with sulphur granules that it is difficult to study the structure of the protoplast while these are present. They may readily be re-

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moved with alcohol, however, without seriously injuring the cell structure, if the material is previously killed in potasium iodide-iodine or in Flemming's solution. Figs. 28 and 29 respectively represent optical longitudinal and cross sections of *Beggiatoa arachnoidea,* killed in Flemming's solution, dehydrated in alcohol until all of the sulphur was dissolved out, and then stained with Loeffler's methylene blue. By this treatment the protoplast is seen to consist of a regular coarse network uniform throughout the cell, with the exception of a very narrow zone next to the cell-wall. This seems to indicate a slight differentiation of the protoplast in the direction of the simplest differentiation found in the Cyanophyceae, such as represented by Fig. 1. Iron haematoxylin and some other chromatin stains differentiate the cell structures in the same manner. As to the differentiation into two zones, my results correspond quite closely to Bütschli's interpretation of the structure of *Beggiatoa alba.* with the difference, however, that in my preparations the "central body" does not appear homogeneous, but consists of a network which occasionally extends to the cell membrane. I am not prepared to say whether this network contains chromatin or not. It seems quite probable that it does contain chromatin, however, for Macallum has shown that iron and phosphorus, the essential elements of chromatin, are distributed throughout the cell. Should it prove to be true that this network does contain chromatin, then the coarse network could well be looked upon as the analogue of a nucleus, and in this species only a slight differentiation has taken place between it and the peripheral cytoplasm. There is not a very great gap between this condition and the one found in the differentiation in *Oscillatoria margaritifera.* Other forms will doubtless be found in which the difference in structure will be even less than the difference between these two species.

In *Beggiatoa mirabilis* there are in every cell a few granules which react in the same way to stains as the α granules in the nucleus of the Cyanophyceae, and these are not affected by the stains which color the β granules found in the cytoplasm of the Cyanophyceae. There is undoubtedly a close genetic connection between the *Beggiatoas* and the homocysted forms of Cyanophyceae, particularly the *Oscillatorias.*

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VII. RESULTS.

1. The cell of the Cyanophyceae contains a nucleus which in some species is sharply delimited from the surrounding cytoplasm, while in others the differentiation is much less marked.

2. The nucleus occupies a relatively large portion of the cell, its shape being determined by the shape of the cell. In short-celled filamentous species its greater diameter is across the filament, while in long-celled species it extends in the direction of the long diameter of the cell.

3. In all the species studied, with the possible exception of *Synechocystis,* the nucleus divides amitotically, beginning at the periphery and gradually proceeding to the center. In *Synechocystis aquatilis* a primitive form of mitosis has developed, in which there is a spireme formed which separates into three pieces. These arrange themselves parallel to each other and to the long diameter of the cell, after which they are divided crosswise, and the ingrowing cell-wall completes the cell division. No longitudinal splitting of the thread occurs.

4. The nucleus consists of granules, chromatin, and an achromatic ground substance in which the two former substances are imbedded. In some forms (*e.g.*, the large short-celled species of *Oscillatoria*) the chromatin is disposed in the ground substance in the form of disconnected masses; in others (*e.g., Symploca Muscorum*) it is somewhat united into a coarse thread-like mass; and in still other cases (*e.g., Dermocarpa*) the chromatin is united into a definite network.

5. The nucleus may be induced to assume a resting condition by very slow desiccation.

6. There is no definitely organized chromatophore, the cytoplasm holding the coloring matters.

7. Cell division is completed in the filamentous forms by the gradual ingrowing of the ring-shaped cell-wall. The division of the chromatin in some species seems to precede the ingrowing of the cell-wall; in others it accompanies it, beginning at the outside of the mass, and keeping pace with the ingrowing wall; and in still other species the cell-wall actually grows to and against the chromatin, gradually crowding it toward the center as if it

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were cutting it in two. In *Dermocarpa* the nucleus breaks up simultaneously into a large number of daughter nuclei; the process is amitotic.

8. Two kinds of granules have been demonstrated in the Cyanophyceae cell. One kind, designated as α granules, is located in the nucleus of the vegetative cell in close proximity to the chromatin (this kind is not present in the mature spore); the other kind, designated as β granules, may or may not be present in the vegetative cell, but is always present in the mature spore. The age of the plant, physiological conditions, and variation in nutrition are probably the determining agencies affecting the presence or absence of the β granules.

9. No protoplasmic continuity between the vegetative cells has been demonstrated.

10. Change in habitat does not produce any marked change in cytological characters.

11. One of the products of assimilation is glycogen. Sugar is probably one of the first products of assimilation.

VIII. SUMMARY.

A new type of nuclear division has been discovered in *Dermocarpa* in which the nucleus breaks up simultaneously into a large number of daughter nuclei by a process of amitosis. (See Figs. 33, 34.)

The present investigation reveals in the Cyanophyceae a series of nuclear structures, beginning with a very simple form of nucleus scarcely differentiated from the surrounding cytoplasm and dividing by simple direct division. From this we pass by very gradual steps to a highly differentiated form of nucleus which in dividing shows a primitive type of mitosis, and in structure approximates the nucleus of the Chlorophyceae and the higher plants. (See Figs. 28, 1 to 5, 40 to 44.)

In this group of plants the transmission of hereditary qualities seems to be accomplished with the greatest precision, without the complicated machinery of mitosis. In this connection it may be noted that the lack of sexuality seems in no wise to affect

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the amount of variation, which is quite the same as in groups where sexual reproduction occurs.

In conclusion I wish to acknowledge my gratitude to Prof. W. J. V. Osterhout, under whose direction the work has been performed, for many helpful suggestions; and to Prof. W. A. Setchell for the determination of the specimens considered in this paper.

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EXPLANATION OF PLATES.

K. I.—Potassium iodide-iodine.

Ehr. Haem.—Ehrlich's haematoxylin.

All of the colored figures represent optical sections and were drawn with the aid of the Abbé camera lucida, Zeiss. Apoc. Hom. Im. Obj. 2.00 mm., Comp. Ocs. 12 and 18.

PLATE 21.

Figs. 1 to 5 present a series showing progressive differentiation of the nucleus. Fig. 28 might be looked upon as the first member of the series.

Fig. 1. *Oscillatoria margaritifera.* Cross section. Ehr. Haem. The outer narrow layer of cytoplasm is denser and composed of a finer network than the portion of the cytoplasm between it and the nucleus. This is true of all the species figured on this plate. The chromatin is in disconnected masses.

Fig. 2. *Oscillatoria limosa.* Cross section. K. I. Ehr. Haem., counterstained with wasserblau 5 seconds. The chromatin is more abundant and more closely connected than in *O. margaritifera.*

Fig. 3. *Oscillatoria chalybea.* Cross section. K. I. Ehr. Haem., counterstained with wasserblau 5 seconds. The nucleus in this species is more concentrated toward the center of the cell than in Fig. 2, and the chromatin is in the form of fine threads, somewhat connected.

Fig. 4. *Oscillatoria Okeni.* Cross section. K. I. Ehr. Haem., counterstained with wasserblau. The nucleus occupies relatively about the same area of the cell as in Fig. 3, though it is more united into thicker masses.

Fig. 5. *Oscillatoria brevis* var. Cross section. K. I. Ehr. Haem. The nucleus is more concentrated than in any of the foregoing species. The chromatin is united into a single very coarse net-like mass.

Fig. 6. *Oscillatoria sancta.* Cross section. K. I. Aqueous thionin. The nucleus is very irregular in outline and the chromatin has a tendency to a radial arrangement.

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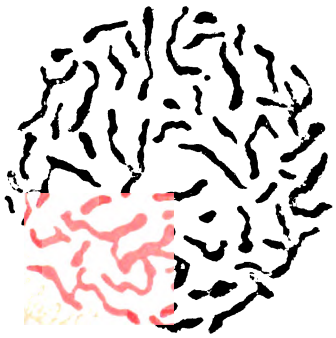

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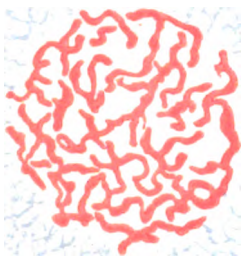

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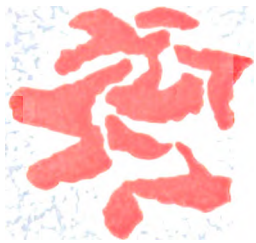

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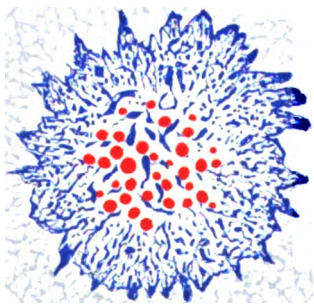

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PLATE 22.

Fig. 7. *Oscillatoria margaritifera.* Longitudinal section. K. I. Ehr. Haem. *a* represents a resting cell, *b* the beginning of cell division, *c* a cell almost divided, and *d* a recently divided cell.

Fig. 8. *Oscillatoria chalybea.* Longitudinal section. K. I. Ehr. Haem. This was stained longer than the preceding in order to bring out the *a* granules in the nucleus. The unstained quadrangular bodies have not been identified.

Fig. 9. *Oscillatoria brevis* var. Longitudinal section. K. I. Ehr. Haem.

Fig. 10. *Oscillatoria Okeni.* Longitudinal section. K. I. Ehr. Haem., counterstained with wasserblau. The cells are slightly shrunken and pulled apart, leaving the dividing nucleus in the sinus. The nucleus occupies nearly the entire length of the cell, and the chromatin has a tendency to arrange itself in the longitudinal direction of the filament.

Fig. 11. *Cylindrospermum licheniforme.* Longitudinal section. Living material stained with Ziel's carbol fuchsin, and counterstained with methylene blue. The first stain colors the cytoplasm and the chromatin red, and these are changed to blue by the second stain, which also stains the granules red. The two cells are slightly pulled apart, showing a strand of chromatin still undivided between the nearly divided cells.

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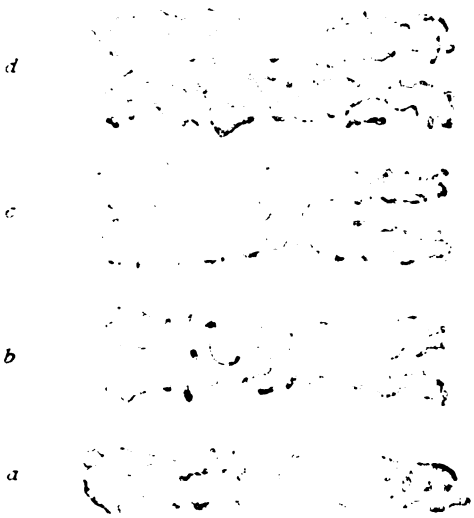

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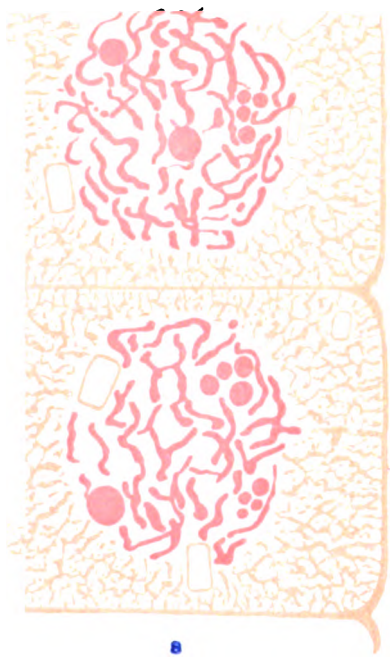

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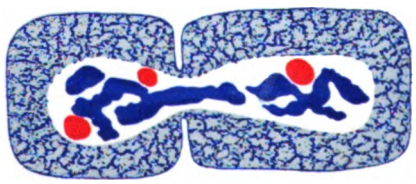

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PLATE 23.

Fig. 12. *Symploca Muscorum.* Longitudinal section. Living material stained with aqueous methylene blue. The cytoplasm has a greenish blue color, the chromatin a deep blue; the granules are red. *a* is a cell just beginning to divide; *b*, the cell-wall has grown into the chromatin, which is just beginning to separate; *c*, division almost completed.

Fig. 13. *Symploca Muscorum.* Longitudinal section. K. I. Ehr. Haem. 30 minutes, counterstained with wasserblau 5 minutes, and washed out with acidulated alcohol, then with Ehr. Haem. again. Wasserblau reveals the β granules in the nucleus and in the cytoplasm.

Fig. 14. *Oscillatoria margaritifera.* Cross section. K. I. Aqueous thionin washed in acidulated alcohol, counterstained with wasserblau and again washed with acidulated alcohol. The α granules are stained red and the β granules are stained blue. They are both here represented in the same plane, but in reality the red ones are in a plane below the blue ones.

Fig. 15. Same species and view as Fig. 14. K. I. Wasserblau washed in acidulated alcohol. Shows only β granules.

Fig. 16. Same species and view as Figs. 14 and 15. K. I. Aqueous thionin washed in acidulated alcohol.

Fig. 17. *Oscillatoria splendida.* Longitudinal section. Living material Ehr. Haem. 5 minutes, counterstained with wasserblau 15 seconds. Ehr. Haem. was not on long enough to stain the α granules, nor was the wasserblau on long enough to stain the β granules.

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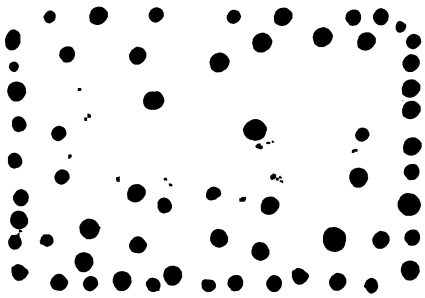
a

b

c

12



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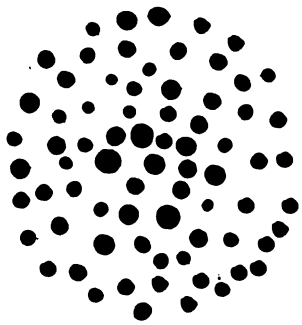

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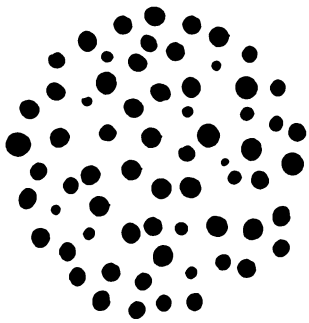

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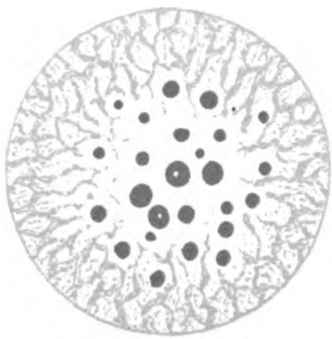

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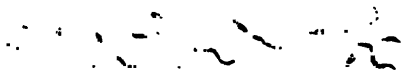

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PLATE 24.

Fig. 18. *Cylindrospermum licheniforme.* Longitudinal section of a young plant. Living material. Ehr. Haem. counterstained with wasserblau, showing the chromatin and α granules stained red and the β granules blue. *a* represents a cell almost divided; in *b*, *c*, and *d* the chromatin is still connected.

Fig. 19. *Cylindrospermum licheniforme.* Longitudinal section. Spore. K. I. Ehr. Haem.

Fig. 20. *Cylindrospermum licheniforme.* Longitudinal section of spore, showing the first division in germination. K. I. Ehr. Haem.

Fig. 21. *Cylindrospermum licheniforme.* Longitudinal section of almost mature spore and two vegetative cells. K. I. Ehr. Haem. counterstained with wasserblau, washed in acidulated alcohol. The Ehr. Haem. stains the α granules and the chromatin in the vegetative cells, but there are no α granules in the spore. The wasserblau stains the β granules.

Fig. 22. *Symploca Muscorum.* Longitudinal section. Ehr. Haem. 3 minutes, showing only chromatin in the nucleus.

Fig. 23. *Oscillatoria Okeni.* Longitudinal section. K. I. Ehr. Haem. counterstained with wasserblau. The β granules are close to the cross-walls and in the outer part of the cytoplasm.

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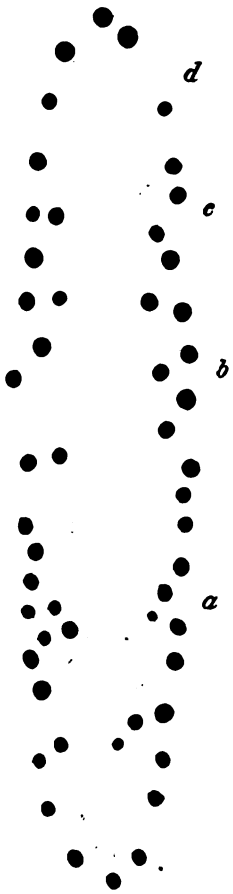

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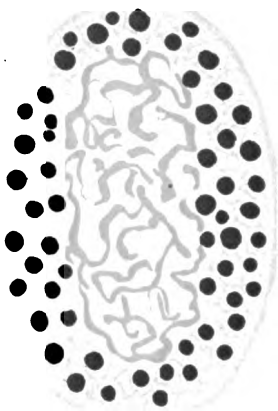

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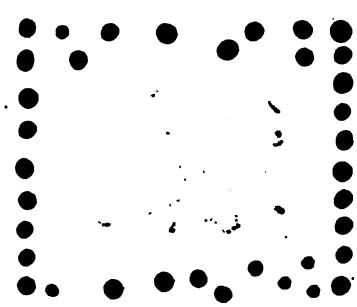

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PLATE 25.

Fig. 24. *Cylindrospermum licheniforme.* Longitudinal section of two cells and a heterocyst. Living material. Ziel's carbol fuchsin, counterstained with wasserblau. The fuchsin kills and stains the cytoplasm and the chromatin. The wasserblau restains these same parts and brings out the β granules.

Fig. 25. Same species, view and treatment as Fig. 24, except the counterstaining with wasserblau.

Fig. 26. Same species and view as Figs. 24 and 25. K. I. Aqueous methylene blue.

Fig. 27. *Oscillatoria brevis* var. Longitudinal section. K. I. Overstained with fuchsin and only partially washed out, showing the nucleus with well defined outline, but the internal structure not differentiated.

Fig. 28. *Beggiatoa arachnoidea.* Longitudinal section. K. I. washed in 95 per cent. alcohol 2 hours to remove iodine and the sulphur granules. Aqueous methylene blue, showing a continuous coarse network which extends to the surface at only a few points. The cytoplasm is made up of a very fine network around the periphery. The cell membrane is very delicate. The red granules are probably the same as the α granules in the Cyanophyceae.

Fig. 29. Cross section of same species as Fig. 28 treated in the same manner.

Fig. 30. *Oscillatoria limosa.* Cross section. K. I. Aqueous thinonin, counterstained with wasserblau and washed in acidulated alcohol. Both α and β granules are shown, and lightly stained chromatin.

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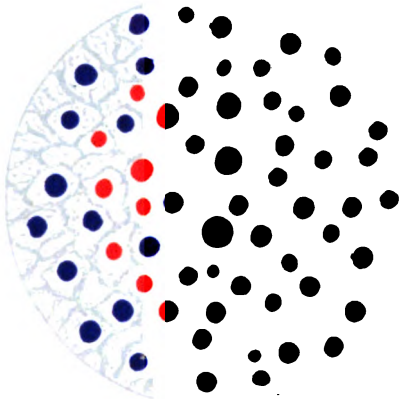

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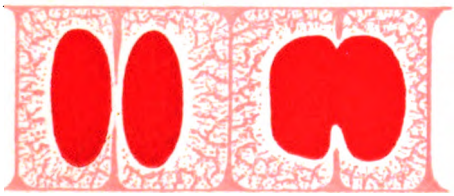

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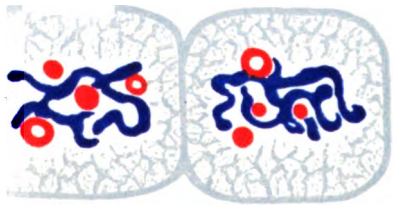

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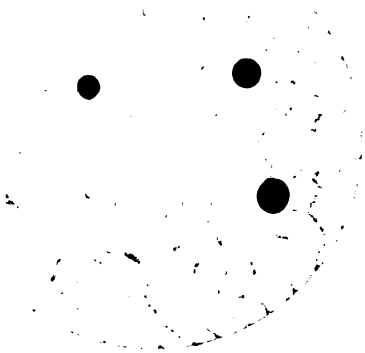

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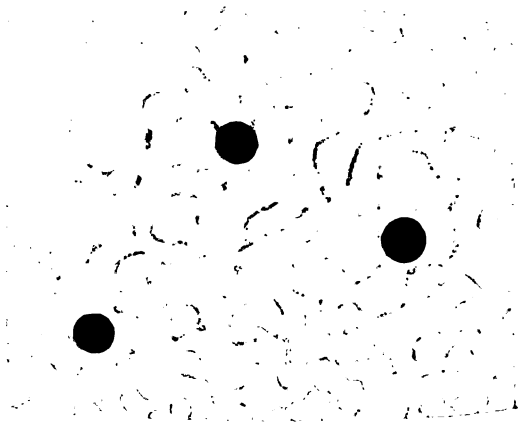

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PLATE 26.

Fig. 31. Section of a young conidium of *Dermocarpa fucicola* shortly after escaping from the parent plant. The chromatin net is beginning to form in the center of the cell.

Fig. 32. Section of a somewhat more advanced stage of *Dermocarpa fucicola* than is shown in Fig. 31. A definite chromatin network has been formed.

Fig. 33. Section of a mature plant of *Dermocarpa fucicola* in vegetative condition, showing a definite network of chromatin occupying the larger part of the cell and surrounded by a thin layer of cytoplasm.

Fig. 34. Section of *Dermocarpa fucicola* showing mature conidia.

Fig. 35. Longitudinal section of *Lyngbya aestuarii* showing the β granules along the cross-cell walls. The larger granules are along the older cell-walls, and new ones are shown arising along the new walls.

Fig. 36. *Oscillatoria chalybea.* Longitudinal view showing the α granules among the fine chromatin threads.

Fig. 37. *Cylindrospermum licheniforme.* The lower cell of the series is dividing, showing the chromatin still connecting the two daughter nuclei.

Fig. 38. *Lyngbya Lagerheimii.* Longitudinal view showing a single irregular chromatin mass and a single α granule in each cell.

Figs. 40-44. *Synechocystis aquatilis.* Showing various stages of cell division. Fig. 40, a resting cell; Fig. 41, beginning of cell division; Fig. 42, beginning of separation of the three masses of chromatin; Fig. 43, more advanced stage; and Fig. 44, two daughter cells before separation.

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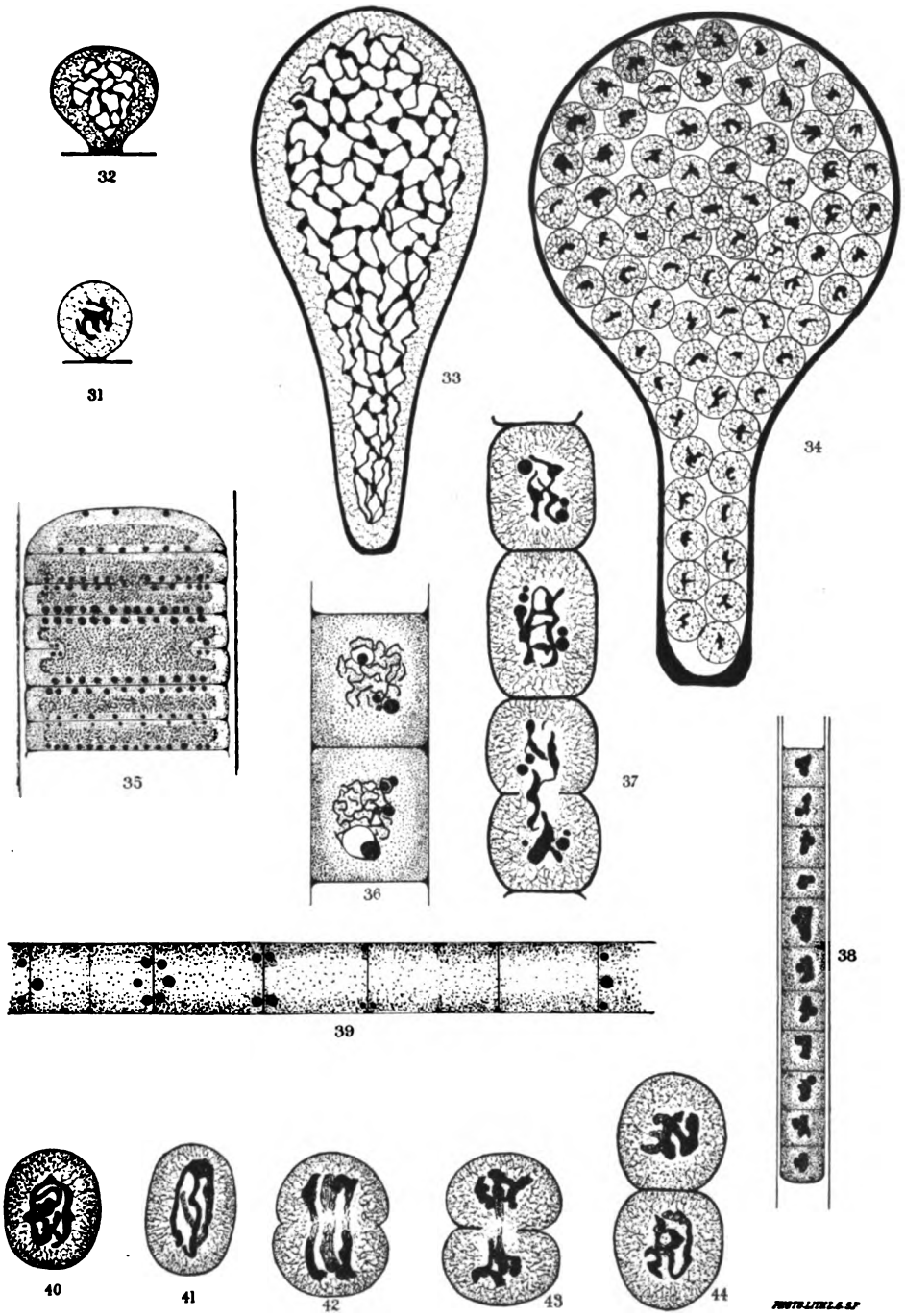

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BY
J. CARDOT and T. THÉRIOT

W. G. FARLOW

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ON A SMALL COLLECTION OF MOSSES FROM ALASKA.

BY

J. CARDOT AND T. THÉRIOT.

We are indebted to the kindness of Mr. W. A. Setchell for a small but very interesting collection of Mosses made in Alaska during the summer of 1899 by himself and Messrs. W. L. Jepson, L. E. Hunt and A. A. Lawson.

This collection comprises 63 species and several varieties, of which 4 species are new to science, and 6 new to Alaska.

DICRANACEAE.

Cynodontium Wahlenbergii Hartm.
Cape Nome (1); St. Michael (58).

Dicranella Grevilleana Sch.
St. Michael (48 in parte).

Dicranella cerviculata Sch.
Cape Nome (70); St. Michael (53 in parte). New to Alaska.

Dicranum elongatum Schl.
St. Michael (49 in parte).
A short, stunted form.

Dicranum groenlandicum Brid.
St. Michael (49).

Dicranum neglectum Jur.
Cape Nome (73 in parte).

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SELIGERIACEAE.

Blindia acuta Br. eur.
Unalaska (6).

Blindia acuta var. **flexipes** Ren. et Card.
Unalaska (3).

DITRICHACEAE.

Ceratodon purpureus Brid.
Unalaska (4, 35 in parte); St. Michael (40, 43).

Distichium capillaceum Br. eur.
Unalaska (6 in parte).

POTTIACEAE.

Desmatodon latifolius Br. eur.
Unalaska (75); Uyak Bay (76).

GRIMMIACEAE.

Grimmia apocarpa Hedw. var. **gracilis** Web. et Mohr.
Unalaska (21).

Grimmia maritima Turn.
Unalaska: Amaknak Island (33).

Rhacomitrium patens Hüb.
Unalaska (22).

Rhacomitrium fasciculare Brid.
Unalaska (18 in parte).

Rhacomitrium heterostichum Brid.
Unalaska (20 in parte).

Rhacomitrium lanuginosum Brid.
St. Michael (56); Cape Nome (67), approaching the form *stricta* Card. et Thér.

Rhacomitrium canescens Brid. var. **ericoides** Br. eur.
Unalaska (13, 20 in parte).

No. 13 is a form remarkable for its nearly smooth hair, a little papillose only at the base.

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ORTHOTRICHACEAE.

Amphoridium lapponicum Sch.

Unalaska (27 in parte, 36).

Ulota phyllantha Brid.

Unalaska (32 in parte).

Belongs to the form *U. maritima* C. Müll. et Kindb.

Orthotrichum arcticum Sch.

Unalaska (19, 32).

No. 32 seems to belong to the var. *Blyttii* (*O. Blyttii* Sch).

Orthotrichum cancellatum Card. et Thér. sp. nov.

Monoicum, densiuscule pulvinatum. Caules ramosi, 1–1.5 centim. alti. Folia sicca imbricata, madida erecto-patentia, media 1.5-1.7 millim. longa, 0.4-0.5 lata, superiora majora, lanceolata vel ovato-lanceolata, acuta mucronatave, marginibus integris usque apicem versus revolutis, costa angusta sub apice evanida, 50-65μ basi crassa, cellulis inferioribus hyalinis vel pellucidis, rectangulis, margines versus brevioribus subquadratis, laevibus, mediis et superioribus inaequalibus, rotundatis vel breviter ovatis, chlorophyllosis, papillosis, diam. 12–18μ, parietibus incrassatis. Flos masculus sub femineo sessilis, foliis perigonialibus brevibus, ovatis, apice rotundatis, ecostatis, marginibus integris. Capsula immersa, in pedicello brevi, 0.5 millim. longo, ovato-pyriformis, madida sensim collo in pedicello defluente attenuata, siccitate sulcata, sub ore constricta, deoperculata circa 1.2 millim. longa, 0.9 crassa, stomatibus emersis, fasciis 8, lutescentibus, e cellulis rectangulis 4-5-seriatis formatis. Calyptra conica, plicatula, pilis paucis albidis ornata, apice brunnea. Vaginula nuda. Peristomium duplex, externum dentibus 8 bigeminatis, vel interdum 16 liberis, siccitate reflexis, granulosis, perforatis et intus in parte superiore eleganter appendiculato-cancellatis, internum ciliis brevioribus, granulosis. Sporae maximae, diam. 30–35μ, papillosae.

Cape Dyer, Norton Sound.

By the elegant structure of the peristomial teeth, this interesting species comes very near *O. fenestratum* Card. et Thér., but differs from it by its smaller size, shorter stems, shorter and more papillose leaves, and the capsule immersed, sulcate in dry state.

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In the "Mosses of Alaska" figures 2*m* and 2*n* of pl. XVI do not give a correct idea of the structure of the peristomial teeth of *O. fenestratum* Card. et Thér., which are like those of *O. cancellatum* as figured here, pl. 27, Fig. 1*m*.

SPLACHNACEAE.

Tetraplodon mnioides Br. eur.
Unalaska (11); St. Michael (55); Cape Nome (63).

Tetraplodon mnioides var. **cavifolius** Sch.
Unalaska (34).

Splachnum sphaericum Linn. fil.
St. Michael (48 in parte).

Splachnum vasculosum Linn.
St. Michael (48 in parte).

BARTRAMIACEAE.

Bartramia ithyphylla Brid.
Unalaska (10 in parte).

Conostomum boreale Sw.
Cape Nome (69).

Philonotis fontana Brid.
Unalaska (26).

Philonotis fontana var. **heterophylla** Card. et Thér. var. nov.

Folia dimorpha, inferiora illis formae normalis fere similia, superiora brevia, imbricata, valde concava, breviter acuminata, marginibus haud vel vix revolutis, rete laxiore, cellulis brevibus composito. Folia perigonialia usque ad apicem distincte costata, interdum in eodem involucro nunc late obtusa, nunc (saepius) subacuta, etiam acuta.

Unalaska (2, 30).

The same form has also been collected at Unalaska by Macoun and by Coville and Kearney, at Yakutat bay and Kodiak by Trelease, at Kukak Bay by Saunders, and in St. Paul Island by Macoun; it seems therefore rather frequent in Alaska.

Philonotis capillaris Lindb.
Unalaska (10 in parte).

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MEESEACEAE.

Meesea uliginosa Hedw.
St. Michael (52).

BRYACEAE.

Webera cruda Bruch.
Unalaska (10 in parte).

Webera proligera Kindb.
Cape Nome (70 in parte).

Bryum inclinatum Br. eur.
Unalaska (9, 10 in parte, 14); St. Michael (39).

Bryum pseudo-Graefianum Card. et Thér. sp. nov.

Dioicum, densissime cespitosum. Caulis erectus, 1 centim. altus, valde radiculosus, ramis brevibus, fragilibus. Folia ad extremitatem caulis et ramorum glomerata, sicca appressa, madida erecto-patentia, concava, ovato-lanceolata, acuminata, costa excurrente cuspidata, media circa 2.2 millim. longa, 1 millim. lata, marginibus integris vel apicem versus remote serrulatis, in 2/3 inferioribus revolutis, costa rubente, excurrente, basi 90-100μ crassa, cellulis inferioribus breviter rectangulis, mediis hexagonis vel rhomboidalibus, valde chlorophyllosis, circa 20μ longis, 12μ latis, marginalibus linearibus, 3-4-seriatis, basin et apicem versus indistinctis. Capsula in pedicello inferne rubello, flexuoso, 10-12 millim. longo pendula, pyriformis, lutescens, circa 3 millim. longa, 1.2 crassa, operculo convexo-mamillato. Annulus latus, duplex vel triplex. Exostomii dentes pallide lutescentes, 0.36 millim. alti, 15-22 lamellis praediti; endostomii processus liberi, in carina late aperti, ciliis nullis vel rudimentariis. Sporae papillosae, diam. 24-30μ.

St. Michael (42).

Differs from *B. Graefianum* Schlieph. and *B. Kaurinianum* Warnst. by its paler capsule and its shorter, smaller and more shortly acuminate leaves, with the costa not so long excurrent. *B. Kaurinianum* has also a much longer pedicel.

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Bryum Setchellii Card. et Thér. sp. nov.

Synoicum. Cespites densi, superne virides, intus nigricantes. Caulis 6-10 millim. altus, ramosus, ramis gracillimis, subjulaceis, fragillimis. Folia minuta, rotundato-ovata, obtusa acutave, circa 1 millim. longa et 0.7 lata, marginibus integris, ubique planis vel basin versus subrevolutis, costa basi 60μ crassa, in foliis inferioribus et mediis sub apice evanida, in superioribus percurrente vel breviter excurrente, cellulis mediis hexagonis rhomboidalibusve, circa 40μ longis, 15-18μ latis, marginalibus parum distinctis, 1-2-seriatis, aliquanto longioribus, lutescentibus. Folia perichaetialia longiora, acuta. Capsula in pedicello atropurpureo, 5-6 millim. longo, pendula, pyriformis, collo ruguloso instructa, circa 2 millim. longa et 1 millim. crassa, operculo conico-mamillato. Annulus latus, triplex. Exostomii dentes 0.36 millim. alti, brunnei, grosse papillosi, 15-20 lamellis prominentibus instructi; endostomii processus liberi, in carina late hyantes, membrana ad tertiam partem dentium producta, ciliis brevissimis vel nullis. Sporae minute muricatulae vel sublaeves, diam. 18-24μ.

St. Michael (41).

Closely allied to *B. agattuense* Phil. from which it is distinguished by its less obtuse leaves, its numerous, slender brittle branches, and its more evolute peristome. From *B. maritimum* Bom. it differs in being synoicous, and by its more numerous and more slender branches and shorter pedicels.

MNIACEAE.

Mnium insigne Mitt.

Unalaska (15).

Mnium punctatum Hedw. var. **elatum** Sch.

Unalaska (29).

Mnium punctatum Hedw. var. **nudum** Card. et Thér. (*M. nudum* Williams).

Unalaska (5, 8).

No. 29, referred to var. *elatum,* is rather intermediate between *M. punctatum* and *M. nudum,* having the areolation of the last, with the thickened margo and the tomentose stems of the var. *elatum.*

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Aulacomnium palustre Schw.

Pastoliak River, near St. Michael (16); St. Michael (54); Cape Nome (65).

POLYTRICHACEAE.

Psilopilum tschuctschicum (C. Müll.) Par. (*Catharinea tschuctschica* C. Müll).

St. Michael (53); Cape Nome (70 in parte, 71).

In *Bryologist,* 1902, No. 5, Mr. John M. Holzinger showed clearly that *P. tschuctschicum* is specifically distinct from *P. arcticum* Brid.; and all the specimens from Alaska and the islands of Behring Sea that we related to *P. arcticum* are to be referred to *P. tschuctschicum.*

Pogonatum capillare Brid. var. **dentatum** Lindb.

Cape Dyer (McGregor, 81).

Pogonatum alpinum Roehl.

Unalaska (10, 35).

Polytrichum gracile Dicks.

Cape Nome (68).

Polytrichum yukonense Card. et Thér. in Proc. Wash. Acad. Sc. IV, p. 329, pl. XXII, f. 1.

Planta fertilis: folia perichaetialia erecta, caulinis fere similia, tamen longiora et in acumen piliforme apice hyalinum producta. Capsula in pedicello rubente, circa 3 centim. longo erecta, parva, 5-6-angulata, deoperculata 2.8 millim. longa, 2.5 lata, hypophysi subdiscoidea, operculo convexo, oblique longirostro. Calyptra subglobosa, totam capsulam obtegens, apice oblique apiculata.

St. Michael (46).

Polytrichum strictum Banks.

Cape Nome (73).

LEUCODONTACEAE.

Antitrichia curtipendula Brid.

Unalaska (18, 23).

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ISOTHECIACEAE.

Climacium ruthenicum Lindb.
Unalaska (31).

HYPNACEAE.

Brachythecium lamprochryseum C. Müll. et Kindb.
Unalaska (2 in parte, 30 in parte, 38).

Plagiothecium pulchellum Br. eur.
Unalaska (27).

Plagiothecium undulatum Br. eur. var. **myurum** Card. et Thér. var. nov.

A forma normali differt: ramis subjulaceis, haud vel vix compressis, foliisque subimbricatis, haud vel parum undulatis, concavis, saepe obtusis.

Unalaska (17 in parte).

A parallel form to *P. neckeroides β myurum* Mol.

Eurhynchium strigosum Br. eur. var. **fallax** Ren. et Card.
Unalaska (9 in parte).

Hypnum fluitans Linn. var. **falcatum** Sch.
St. Michael (57); Cape Nome 72, 74). New to Alaska.

Hypnum fluitans Linn. var. **brachydictyon** Ren.
Cape Nome (66). New to Alaska.

Hypnum capillifolium Warnst.
St. Michael (50). New to Alaska.

Hypnum uncinatum Hedw.
Pastoliak River, near St. Michael (16 in parte); St. Michael (58 in parte); Cape Nome (60).

Hypnum Crista-castrensis Linn.
St. Michael (45).

Hypnum Dieckii Ren. et Card.
Unalaska (25).

Hypnum Bestii Ren. et Bryhn.
Unalaska (28).

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Hypnum giganteum Sch.

Unalaska (37). New to Alaska; but Mr. Williams has reported the var. *fluitans* Klingg. from the Yukon Territory.

Hypnum stramineum Dicks.

Cape Nome (66 in parte).

Hypnum pseudo-sarmentesum Card. et Thér. sp. nov.

Cespites atro-purpurei, nitidi. Caulis erectus, 8-10 centim. altus, irregulariter ramosus vel subpinnatus, ramis sat numerosis, cuspidatulis, brevibus, inaequalibus. Folia caulina erecta, circa 2 millim. longa, 0.8 lata, ramea erecto-patentia, 1.7-1.8 millim. longa, 0.45-0.5 lata, omnia ovato -1 vel oblongo-lanceolata, acute acuminata, marginibus planis, superne inflexis, integerrimis, costa basi 60-70μ crassa, ante apicem evanida, cellulis linearibus, mediis 40-60μ longis, circa 7μ latis, inferioribus brevioribus, rectangulis vel subquadratis, alaribus distinctis, majoribus, oblongis, hyalinis. Folia perichaetialia subvaginantia, externa brevia, enervia, intima elongata, acuminata, nervo excurrente. Capsula in pedicello rubello, 2-3 centim. longo, suberecta, arcuato-cylindrica. Caetera desiderantur.

Cape Nome (64, 73 in parte).

Much like *H. sarmentosum* Wahl. but at first sight distinguished by its acuminate-acute leaves.

Hypnum Schreberi Willd.

St. Michael (51); Cape Nome (68 in parte, 73 in parte).

Hylocomium splendens Br. eur.

Unalaska (7, 17); St. Michael (44, 47); Cape Dyer (82).

No. 17 is a form near var. *gracilius* Boul.

Hylocomium triquetrum Br. eur. var. **behringianum** Card. et Thér.

Unalaska (12).

Hylocomium squarrosum Br. eur.

Unalaska (10 in parte).

Hylocomium rugosum De Not. var. **boreale** Lange. (*Hypnum rugosum β imbricatum* Pfeffer).

Cape Nome (59). New to Alaska.

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EXPLANATION OF PLATES.

PLATE 27.

1. **Orthotrichum cancellatum.**—*a*, entire plant, nat. size; *b*, *b*, leaves × 13; *c*, transverse section of a leaf × 60; *d*, part of the same × 210; *e*, basal areolation of a leaf × 135; *f*, areolation in the middle × 135; *g*, areolation of the apex × 90; *h*, capsule in dry state × 13; *i*, capsule in moist state × 13; *k*, the same split lengthwise × 13; *l*, portion of the peristome and of the capsular membrane × 90; *m*, a tooth of the peristome, seen on the ventral side × 112; *n*, calyptra × 13.

2. **Hypnum pseudo-sarmentosum.**—*a*, entire plant, nat. size; *b*, branch-leaves × 17; *c*, stem-leaves × 17; *d*, basal areolation of a stem-leaf × 135; *e*, areolation in the middle × 135; *f*, apex of a branch-leaf × 90; *g*, *h*, perichaetial-leaves × 17; *i*, apex of a perichaetial-leaf × 90; *j*, capsule immature × 13.

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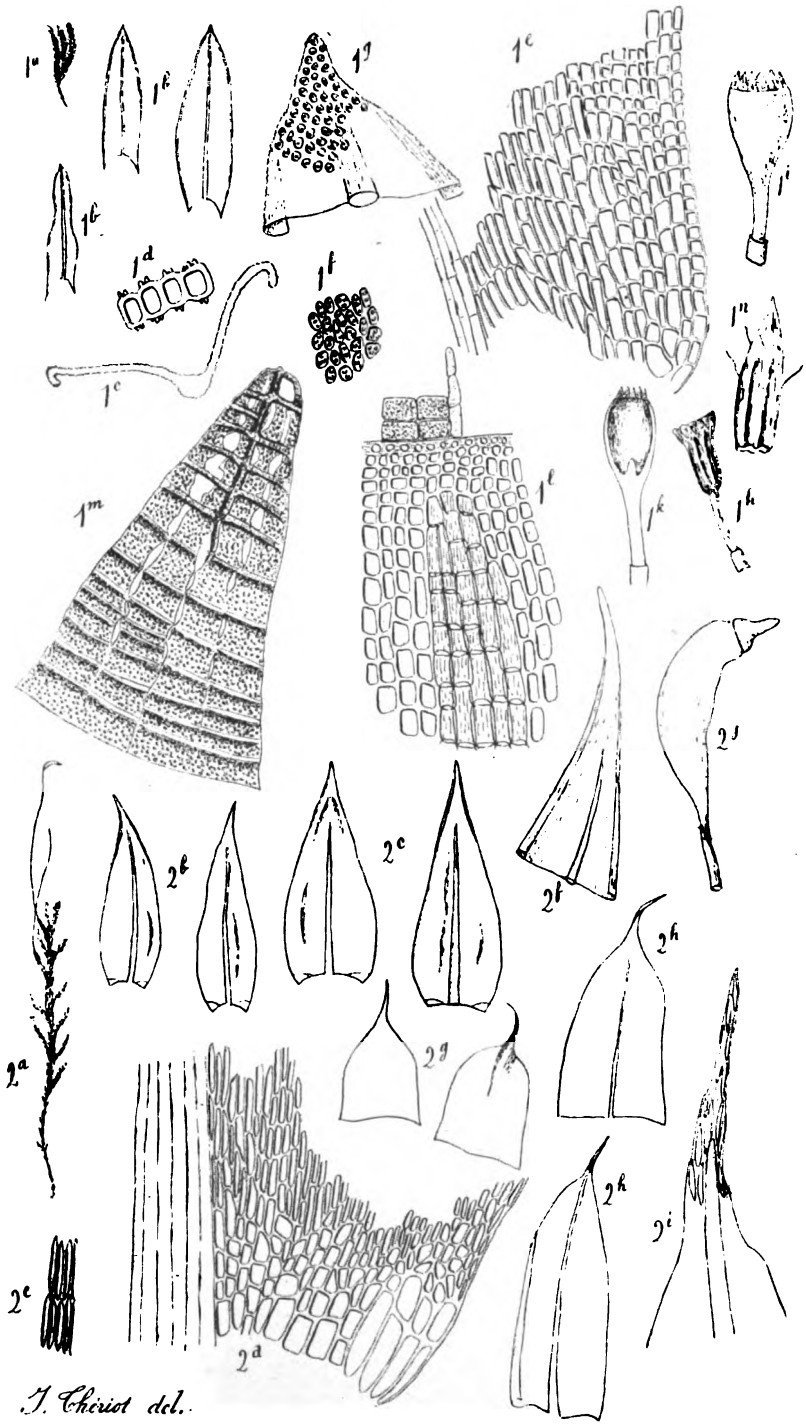

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PLATE 28.

1. **Polytrichum yukonense.**—*a*, entire plant, nat. size; *b*, capsule × 13; *c*, transverse section of the capsules × 13.

2. **Bryum Setchellii.**—*a*, entire plant, nat. size; *b*, *c*, *d*, stem-leaves × 13; *e*, *f*, perichaetial leaves × 13; *g*, basal areolation of a stem-leaf × 135; *h*, marginal areolation, in the middle × 135; *i*, areolation of the apex of a lower leaf × 135; *j*, areolation of the apex of a median leaf × 135; *k*, capsule in dry state × 13; *l*, capsule in moist state × 13; *m*, portion of the annulus × 135; *n*, portion of the peristome × 90.

3. **Byrum pseudo-Graefianum.**—*a*, *b*, entire plants, nat. size; *c*, lower leaf × 13; *d*, upper leaf × 13; *e*, perichaetial leaf × 13; *f*, basal areolation of a stem-leaf × 135; *g*, marginal areolation in the middle × 135; *h*, areolation in the middle, near the nerve × 135; *i*, areolation of the apex × 135; *j*, portion of synoicous flower × 60; *k*, capsule in dry state × 13; *l*, capsule in moist state × 13; *m*, portion of the peristome × 90; *n*, portion of the annulus × 135.

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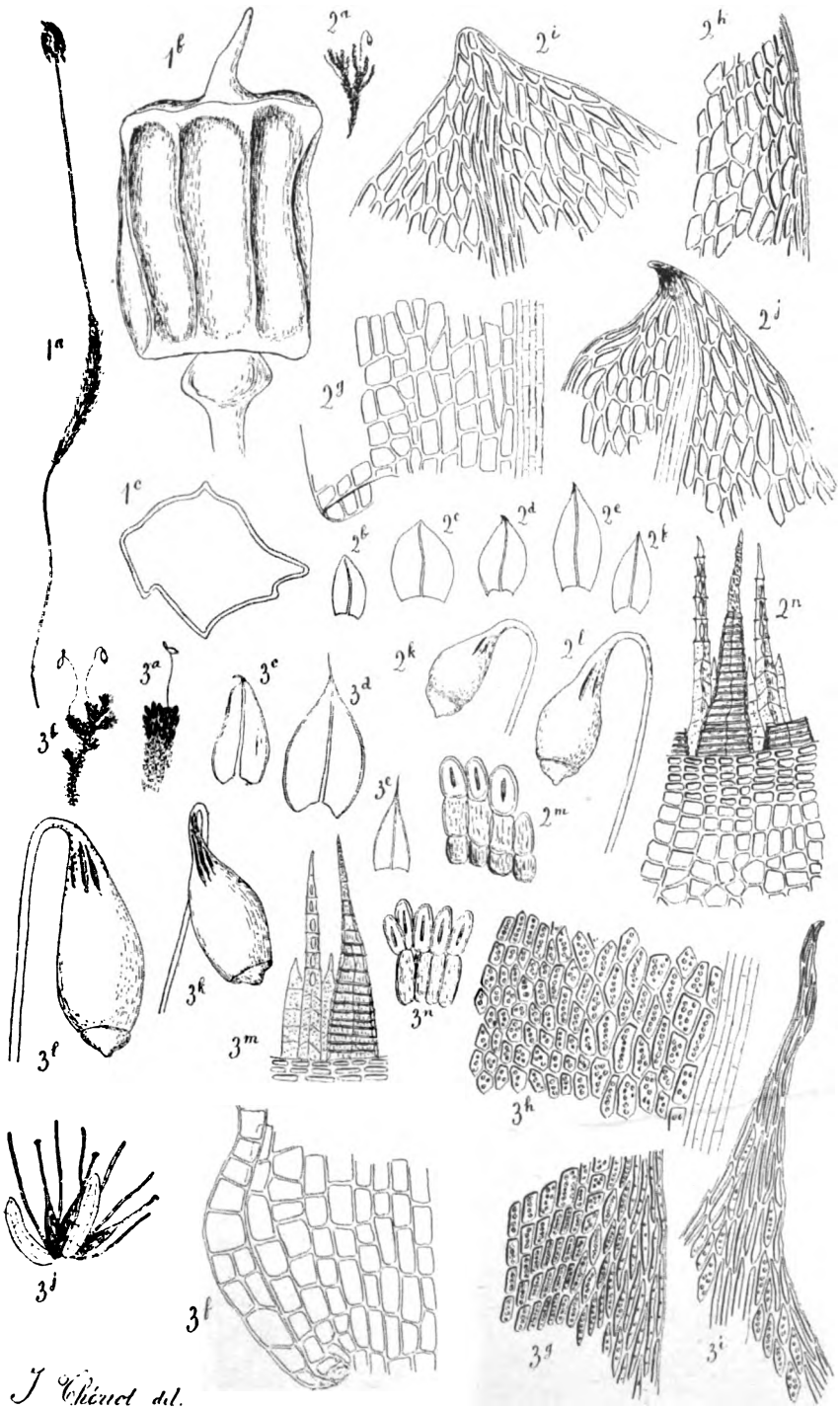

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SOME UNREPORTED ALASKAN SPHAGNA,

TOGETHER WITH A SUMMARY OF THE CRYPTOGAMIC WORK OF THE UNIVERSITY OF CALIFORNIA BOTANICAL EXPEDITION TO ALASKA IN 1899.

BY
WILLIAM ALBERT SETCHELL

W. G. FARLOW

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BY

WILLIAM ALBERT SETCHELL.

The summer of 1899 saw the most extensive explorations of the coasts of Alaska, at least in so far as the natural history of the territory is concerned, of any summer thus far. The members of the party, who were the guests of Mr. Edward H. Harriman, and who constituted the scientific corps of the Harriman Alaskan Expedition, had unrivaled opportunities, and the results, published by Doubleday, Page & Co., under the editorship of Dr. C. Hart Merriam, in the magnificent volumes entitled *Alaska,* fully come up to expectation. In these volumes we find an enormous quantity of material on the geography, geology, zoology, and botany of our little known territory.

For some years the writer had made similar plans and in the year preceding the Harriman Expedition four of the members of the University of California had made reasonably definite arrangements to attempt some limited botanical exploration in the same general field, and especially had set their eyes on the region of the Island of Unalaska, at the southeastern corner of the Bering Sea. The members of this minor expedition were W. L. Jepson, Assistant Professor of Botany; A. A. Lawson.

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graduate student in Botany; L. E. Hunt, Instructor in Civil Engineering, and the writer. Our expenses were necessarily borne by ourselves, but, through the kind representations of Professor George Davidson, most liberal reductions in the cost of transportation and other assistance was generously accorded us by the Alaska Commercial Company, the Pacific Steam Whaling Company, and the Pacific Coast Steamship Company, all of San Francisco, without which the various trips would have been impossible for us.

We proceeded from San Francisco in a ship belonging to the Alaska Commercial Company and landed at the village of Iliuliuk, on the Island of Unalaska, in late June. We made this our headquarters for nine weeks, and from this spot made botanizing trips to as much of the immediate vicinity as possible. Our stay in Unalaska enabled us to explore this small bit of territory with some thoroughness. The writer, also, was enabled to do some exploring in the neighborhood of St. Michael and Cape Nome, through the courtesy of the officers of the steamer Patterson of the U. S. Coast and Geodetic Survey. In all, about three weeks were spent away from Unalaska in this region. Returning, we were able to make some collections at Karluk, Uyak Bay, and St. Paul on Kadiak Island, at Delarof Harbor on Unga Island, at Orca in the region of Prince William Sound, at Juneau, and at Sitka.

Our collections from all these places, while reasonably extensive, considering the smallness of our personnel and the limited number of localities visited, are small in comparison with the wealth of material brought back by the Harriman Expedition. Still, they supplement them to some extent, especially in the region of Bering Sea, have added some interesting information, and have helped to enrich the herbarium of the University of California with considerable valuable Alaskan material.

The very considerable collections of flowering plants are still in the hands of Professor Jepson for study and report. The lower plants, however, have now been thoroughly worked over, either by the writer or by the specialists to whom he has submitted them, and are all named and arranged in their proper places in our collections.

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The cryptogamic material from Alaska outside the region of Bering Sea was, in accordance with our original plan, sent to Professor William Trelease, in charge of the cryptogamic work of the Harriman Expedition, and have been reported upon in the various papers which make up Vol. V of the Harriman Report. The Algae, however, were not thus sent, while, in the case of the Lichens, all of our Alaskan material was thus sent. In order that a convenient record may be made of the various reports upon the cryptogams collected by us, I add a brief resume under the proper group headings.

ALGAE.

One of the algae obtained in the neighborhood of Iliuliuk has been reported upon by Miss Minnie Reed in her paper entitled "Two new Ascomycetous Fungi Parasitic on Marine Algae," published in the first volume of this series (University of California Publications, Botany, Vol. I, pp. 141-164, 1902). The rest of the algae collected in Alaska were included in the paper by Setchell and Gardner, the "Algae of Northwestern America," which forms pp. 165-418 of Vol. I of this series.

FUNGI.

Comparatively little attention was paid by any one of us to the members of this group. The larger and more conspicuous species seemed to be scanty of occurrence in the regions where our opportunities for collection were favorable, and the phaenogamic portion of our collections has not been carefully examined for the presence of the more inconspicuous and parasitic species. Consequently only about half a dozen can be reported. Three parasitic species are included in the report of Professor William Trelease in Vol. V of the Harriman Expedition's publications, and two others *Empusa Muscae* and a large sclerotium of some species of Claviceps were common on a species of Elymus near the canneries at Uyak Bay. A few fleshy agarics were noted on the Island of Unalaska, but no good specimens were obtained.

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One very interesting form, parasitic on a marine alga, has been described by Miss Reed, under the name of *Guignardella Alaskana* in the paper spoken of just above.

LICHENS.

All the lichens collected were sent to Professor Clara E. Cummings, and are included in her account of this group in Vol. V of the Harriman Expedition.

BRYOPHYTES.

Only the hepaticae of the regions along the coasts to the south and east of Bering Sea were sent at first to be worked over with those of the Harriman Expedition, and only those were included in the account of these plants by Professor A. W. Evans in Vol. V of *Alaska*. Later the collections of hepaticae from Unalaska, Cape Nome, and the vicinity of St. Michael were also sent to Professor Evans, who made a special report upon them in an article entitled "Hepaticae collected by W. A. Setchell in Northern Alaska," published in *Zoe* (Vol. V, pp. 129-132, 1901).

All the specimens of mosses collected by us in Alaska to the south and east of Bering Sea were sent to Professor Trelease, and were reported upon in the accounts of these plants published in Vol. V of the Harriman Expedition's *Alaska*. The mosses of the Bering Sea region were, however, later submitted to Messrs. J. Cardot and I. Thériot, whose report is published in the present volume of this series (University of California Publications, Botany, Vol. II, pp. 297-308, 1906).

The species of Sphagnum or peat-moss, collected by us in the tundras of the coasts of the Bering Sea region, have all been determined by Dr. Carl Warnstorf of Berlin, and a list of these is inserted here. In this list there are added to the flora of Alaska three species and eight varieties, with one variety new to science whose description is given below as Dr. Warnstorf wrote it. Altogether, there are now known from Alaska twenty-five species and twenty-eight varieties.

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LIST OF ALASKAN SPECIES OF SPHAGNUM ACCORDING TO THE DETERMINATIONS OF DR. CARL WARNSTORF.

S. acutifolium var. **versicolor** Warnstorf.

Unalaska, No. 1500. Westward extension of range in Alaska.

S. Dusenii var. **majus** (Russ.)

Cape Nome, No. 2594. Species and variety new to Alaska.

S. fimbriatum var. **concinnum** Berggr.

Cape Nome, Nos. 2590 and 2593; St. Michael, Nos. 80 and 1951 (the two latter numbers collected by H. W. Rhodes and P. M. Newhall). Variety new to Alaska.

S. fimbriatum var. **flavescens** Warnstorf n. var.

In dichten, oberwärts gelblichen, nach unten ausgebleichten, 12-15 cm. tiefen weichen Rasen, die nach oben stark verbreiteten Stammblätter bis zur Mitte und weiter herab an den Rändern gefranst Astbüschel gedrängt; die abstehenden Aeste durch die dicht dachziegelig gelagerten Blätter rundlich aufrecht abstehend bogig zurückgekrümmt und z. T. aufstrebend; ihre Blätter klein, eiförmig bis eilanzettlich, etwa 0.7-1.06 mm. lang und 0.5 mm. breit und an der schmal gestutzten Spitze kaum gezähnt oder klein zweizähnig. Zweihäusig; die weiblichen Blüten in der Kegel nur mit einem unbefruchteten Archegonium. Von var. *concinnum* fast nur durch die verschiedene Richtung der stärkeren Aeste abweichend!

Cape Nome, No. 2592.

S. fimbriatum var. **robustum** Braithw.

St. Michael, No. 1957. Variety new to Alaska.

S. fuscum var. Klinggr.

St. Michael, No. 1960.

S. Girgensohnii Russ.

St. Michael (Cape Dyer), No. 79, collected by H. W. Rhodes and P. M. Newhall; Unalaska, Nos. 1506 and 1509; Orca, Nos. 1223, 1224, and 1225. This species is apparently common along

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the entire coast region of Alaska. The Orca specimens have been noted by Trelease in the list of species collected by the Harriman Expedition.

S. Lindbergi var. **macrophyllum** f. **fluitans** Warnstorf.

St. Michael, No. 1965. Variety and form new to Alaska.

S. Lindbergi var. **mesophyllum** Warnstorf.

St. Michael, No. 1956. Variety new to Alaska.

S. medium Limpr.

St. Michael, No. 1961. Northward extension of range in Alaska.

S. medium var. **obscurum** f. **brachy-dasycladum** Warnstorf.

Cape Nome, No. 2591. Variety and form new to Alaska.

S. platyphyllum var. **immersum** Warnstorf.

St. Michael, No. 1958. Species and variety new to Alaska.

S. recurvum var. **amblyphyllum** (Russ.)

St. Michael, No. 1954. Variety new to Alaska.

S. rubellum Wils.

St. Michael, No. 1962; Unalaska, No. 83. Westward and northward extension of the range in Alaska.

S. squarrosum Pers.

St. Michael, Nos. 1952 and 1953.

S. squarrosum var. **imbricatum** Schmpr.

Pastoliak River, near St. Michael, P. M. Newhall, No. 1950. Of wide distribution in the coast region of Alaska bordering on Bering Sea.

S. squarrosum var. **subsquarrosum** (Russ.)

St. Michael, No. 1959; Unalaska, No. 1507.

S. subbicolor var. **flavescens** (Russ.) Warnstorf.

Unalaska, Nos. 1501 and 1508. Species and variety new to Alaska.

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S. teres var. **imbricatum** Warnstorf.

Unalaska, Nos. 1502 and 1503. Variety new to Alaska.

S. Warnstorfii var. **flavescens** Russ.

Unalaska, No. 1505. Variety new to Alaska.

S. Warnstorfii var. **purpurascens** Russ.

Unalaska, No. 1504. Slight extension of range westward in Alaska.

PTERIDOPHYTES.

A number of species of ferns and of fern allies were collected and have been determined and inserted in the herbarium, but there is nothing to be added to the very complete enumeration of these plants given in the account in Vol. V of the Report of the Harriman Expedition.

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INDEX.*

Aalaula, 96, 97, 107, 112, 113.
Agaricus, 176.
Agarum fimbriatum, 125, 126.
  Turneri, 124, 125, 126, 150.
Ahnfeldtia Polyides, 97.
Akiaki, 93, 96, 97, 98, 102, 103.
Ahnfeldtia concinna, 97.
  Gigartinoides, 97.
Ako'ako'a, 97.
Alaalaula, 97.
Alani, 97.
Alaria esculenta, 117, 146, 149, 158.
Alaskan Sphagna, Some Unreported, 309.
Alaula, 96, 97.
Algae, 311.
Amansia glomerata, 106.
Amphoridium lapponicum, 299.
Anabaena, 239.
  Azollae, 239.
  catenula, 250.
  flos-aquae, 239, 251.
  variabilis, 239, 271.
Anadyomene stellata, 158.
Antitoxic Action of Potassium on Magnesium, 235.
Antitrichia curtipendula, 303.
Aphanizomenon Flos-aquae, 239.
Aphanothece, 239, 277.
Aqueous Media, Mounting in, 83.
Arctium Lappa, 159.
Arthrothamnus bifidus, 128.
  Bongardianus, 117, 121.
  Bongardianus var. furcatus, 121.
Ascomycetous Fungi, New Genus of, 169.
Asparagopsis Sanfordiana, 103, 104, 105.
Atonement Limu, 96.
Aulacomnium palustre, 303.
Aupupu, 97.

Balanced Solutions, and Nutrient, 317.
  For plants, On Physiologically, 231.
Bartramia ithyphylla, 300.
Beggiatoa, 278.
  alba, 278, 279.
  arachnoidea, 240, 279.
  mirabilis, 240, 278, 279.
Begonia, 157.
Blindia acuta, 298.
  var. flexipes, 298.
Boletus, 176.
Brachythecium lamprochryseum, 304.
Bryum Graefianum, 301.
  inclinatum, 301.
  Kaurinianum, 301.
  pseudo-Graefianum, 301.
  Setchellii, 302.
Bryophytes, 312.
Burdock, 159.

Calothrix, 251.
  Braunii, 239.
  crustacea, 239.
  parietina, 239.
Catharinea tschuctschica, 303.
Ceratodon purpureus, 298.
Centroceras clavulatum, 102, 112.
Chaetomorpha antennina, 109.
Chamaesiphonaceae, 239.
Chondrus affinis, 102.
Chorda filum, 116.
  tomentosa, 116.
Chroococcaceae, 239.
Claviceps, 311.
Climacium ruthenicum, 304.
Codium Muelleri, 96, 97, 113.
  spongiosum, 100.
Colonectria Massariae, 176.
Colpomenia sinuosa, 113.
Conostomum boreale, 300.
Contributions to Cytological technique, 73.
Cyanophyceae, 237.
  Cytological Studies in, 237.
Cylindrospermum, 251, 259, 264, 271.
  licheniforme, 239.
  macrospermum, 251.
  majus, 239.
Cynodontium Wahlenbergii, 297.
Cytological Studies in Cyanophyceae, 237.
Cytological Technique, 73.

* Vol. 2, Univ. Calif. Publ. Bot.

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Dehydration, Embedding with Incomplete, 87.
Dermocarpa, 264, 267, 280, 281.
fucicola, 239, 264.
prasina, 239, 264.
Desmatodon latifolius, 298.
Dicranella cerviculata, 297.
Grevilleana, 297.
Dicranum elongatum, 297.
groenlandicum, 297.
neglectum, 297.
Dictyosphaeria favulosa, 107.
Dictyotaceae, 106.
Dictyota divaricata, 106.
patens J., 106.
Distichium capillaceum, 298.
Dodder, 102.

Ecklonia bicyclis, 128, 129.
buccinalis, 118.
cava, 129, 130.
Ectocarpus confervoides, 230.
Ehau, 97.
Eisenia arborea, 126, 128, 129, 149.
arborea f. bicyclis, 129.
bicyclis, 129, 149.
Ekaha, 97.
Ekahakaha, 96, 98.
Eleau, 98.
Eleele, 98.
Embedding with Incomplete Dehydration, 87.
Microscopic Algae, 85.
Empusa Muscae, 311.
Enteromorpha, 234.
Hopkirkii, 229, 234.
intestinalis, 98.
Eurhynchium strigosum var. fallax, 304.

Fixation in Vacuo, 78.
Freezing Microtome, 73.
Fucus, 157, 158.
Fungi, 311.
Fungi, New Genus of Ascomycetous, 169.

Galaxaura lapidescens, 113.
rugosa, 102, 110.
Gelidium Amansii, 107.
capillaceum, 154.
filicinum, 108.
Gloeocapsa, 251, 252, 253, 255, 257.
polydermatica, 251.
Gloeotrichia, 251.
Gracilaria coronopifolia, 104, 108.
Grateloupia filicina, 99.
Grimmia apocarpa var. gracilis, 298.
maritima, 298.
Guignardella Alaskana, 312.
Gymnogongrus vermicularis f. Americana, 102.

Godetias, Synopsis of the North American, 319.
Index, 353.

Hafgygia Bongardiana, 118.
Bongardiana forma subsessilis, 119, 121.
Sinclairii, 142.
Haligenia bulbosa, 116.
Halimeda, 97.
Haliseris plagiogramma, 106.
Hassallia byssoidea, 239.
Hedophylleae, 126.
Hedophyllum sessile, 119, 120, 123, 126.
spirale, 120, 122, 125, 126, 128.
subsessile, 118, 120, 121, 122, 125, 126.
Heterocysteae, 239.
Hihimanu, 107.
Hinaula, 98.
Holomoku, 99.
Homocysteae, 239.
Hona, 99.
Hoonunu, 99.
Huahuakai, 99.
Huluhuluwaena, 93, 95, 99, 111.
Huluilio, 99.
Hululio, 99.
Huna, 99, 100.
Hune, 100.
Hunehune, 100.
Huwae, 100.
Huwai, 100.
Hydroclathrus cancellatus, 113.
Hylocomium rugosum var. boreale, 305.
splendens, 305.
squarrosum, 305.
triquetrum var. behringianum, 305.
Hypnea nidifica, 99, 100, 109, 110.
Hypnum, Bestii, 304.
capillifolium, 304.
Crista-castrensis, 304.
Dieckii, 304.
fluitans var. brachydictyon, 304.
fluitans var. falcatum, 304.
giganteum, 305.
var. fluitans, 305.
pseudo-sarmentosum, 305.
rugosum β imbricatum, 305.
sarmentosum, 305.
Schreiberi, 305.
stramineum, 305.
uncinatum, 304.
Hypocrea, 178.
inclusa, 176.
rufa, 176.
Hypomyces chrysospermus, 176.
Melanostigma, 176.
terrestris, 176.
tubericola, 176.

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Ilioha, 100.

Jania rubens, 99.
Juglans, 207.

Kahakala, 100.
Kala, 100.
Kalalauliilii, 101.
Kalalaunuinui, 101.
Kaunoa, 102.
Kele, 102.
Kelps, Regeneration among, 139.
Kiki, 102.
Koeleele, 96, 97, 98, 102, 103.
Kohu, 103.
Koiale, 103.
Koko, 103.
Koloa, 103.
Kukaepueo, 103.
Kulapepeiao, 104.
Kumulinukala, 104, 107.
Kumulipoa, 104, 107.

Laminaria Andersonii, 145, 149.
  apoda, 119.
  Bongardiana, 149.
  Bongardiana f. bifurcata, 121.
  Bongardiana, forma brevipes, 121.
  digitata, 149, 158.
  Farlowii, 146.
  longicruris, 150.
  phyllitis, 117.
  saccharina, 116, 117, 126, 150.
  sessilis, 119, 121.
  Sinclairii, 121, 140, 141, 142, 144, 145, 146, 148, 149, 150, 151, 154, 158.
Laminariaceae, Post-embryonal stages of, 115.
Laurencia obtusa var. racemosa, 99, 100, 106, 108.
  perforata, 112.
Lessonia laminariaeoides, 146.
  litoralis, 118.
Liagora valida, 112.
Lichens, 312.
Limu, 91.
  akiaki, 97.
  alani, 97, 108.
  aupupu, 97.
  ekaha, 97.
  ekahakaha, 98.
  eleele, 98, 112.
  hinaula, 98.
  holomoku, 99.
  hona, 99, 100.
  huahuakai, 99.
  huluilio, 99.
  huna, 99, 100.
  hune, 100.
  hunehune, 100.
  kahakala, 100.
  kala, 96, 100, 101, 104.
  kalalauliilii, 101.
  kalalaunuinui, 101.
  kele, 102.
  kiki, 102.
  koeleele, 102.
  kohu, 103, 104.
  koiale, 103.
  koko, 103, 104.
  koloa, 103.
  kumulimukala, 104.
  kumulipoa, 104.
  lipahapala, 104.
  lipakai, 105.
  lipalao, 105.
  lipalawai, 105, 112.
  lipehu, 106.
  lipewale, 106.
  lipoa, 107.
  lipuula, 107.
  lipuupuu, 107.
  loloa, 107.
  lupe, 107.
  makaloa, 108.
  make, 97.
  maneoneo, 108.
  mauauwea, 108.
  nano, 109.
  nanoo, 109.
  nanue, 109.
  onoaka, 109.
  ohiohio, 110.
  okupe, 110.
  oohiea, 110.
  opai, 110.
  paakai, 110.
  paakaiea, 110.
  pahapaha, 110, 111.
  pakeleawaa, 111.
  palahalaha, 111.
  palawai, 105, 112.
  pehu, 112.
  pepeiao, 112.
  pepeulu, 113.
  pipilani, 113.
  pupukaneilio, 113.
  salt, 104, 105, 110.
  uaualoli, 113.
  ulaula, 113.
  wawahiwaa, 113.
Limuaalaula, 96.
Limuhinaula, 98.
Limuhululio, 99.
Limuhuna, 100.
Limukahakala, 100.
Limukala, 100, 107.

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Limukele, 102.
Limukiki, 102.
Limukoko, 103.
Limulipahapala, 104.
Limulipalao, 105.
Limulipalawai, 105, 112.
Limulipoa, 107.
Limulipupu, 107.
Limulipuula, 107.
Limulipuupuu, 107.
Limuloloa, 107.
Limunanue, 109.
Limuopai, 110.
Limupaakaiea, 110.
Limupalahalaha, 111.
Limupalawai, 105, 112.
Limupipilani, 113.
Limuulaula, 113.
Lipaakai, 104, 105, 106, 110.
Lipaha, 104.
Lipahapala, 104.
Lipahee, 105, 111.
Lipakai, 105.
Lipalahalaha, 105, 111.
Lipalao, 105.
Lipalawai, 105.
Lipalu, 106.
Lipeepee, 105, 107, 108, 112.
Lipehu, 106.
Lipewale, 106.
Lipoa, 92, 104, 106, 109.
Lipupu, 107.
Lipuula, 107.
Lipuupuu, 107.
Loloa, 107.
Lunularia, 157, 233, 236.
  vulgaris, 154, 158.
Lupe, 107.
Lyngbya, 234.
  aestuarii, 229, 239, 273, 277.
  Lagerheimii, 239, 270.

Magnesium, Antitoxic Action of Potassium on, 235.
Makaloa, 108.
Make, 108.
Manaiea, 108.
Manauea, 108.
Manauwea, 95, 108.
Maneoneo, 108.
Marchantia, 157, 158.
  polymorpha, 154.
Massaria inquinans, 176.
Mauauwea, 108.
Meesea uliginosa, 301.
Melanogaster, 176.
Melanospora Helvellae, 176.
Merismopedia, 270.
  Gardneri, 239.
  glauca, 239.
Microcoleus chthonoplastes, 239.
Microscopic Algae, embedding, 85.
Microtome, Freezing, 73.
Mnium insigne, 302.
  nudum, 302.
  punctatum, 302.
  punctatum var. elatum, 302.
  punctatum var. nudum, 302.
Monostroma, 105, 111, 112.
  latissimum, 110.
Mounting in Aqueous Media, 83.
Mualea, 108, 109.
Myrica, 207.

Nanea, 109.
Nanoo, 109.
Nanue, 109.
Nanui, 109.
Nectria lichenicola, 176.
  Robergei, 176.
Nereocystis, 118.
  Luetkeana, 149.
New Genus of Ascomycetous Fungi, 169.
Nigrosphaeria, 179.
  Setchellii, 179.
Nitophyllum multilobum, 230.
Nodularia armorica, 239.
  sphaerocarpa, 239.
Nohomahe, 109.
Nostoc, 251.
  caeruleum, 250.
  ellipsosporium, 239.
  microscopicum, 239.
  pruniforme, 239.
Nutrient and Balanced Solutions, 317.

Oaoaka, 109.
Octaviana, 176.
Ohiohio, 110.
Okala, 110.
Okupe, 110.
On a Small Collection of Mosses from Alaska, 297.
On the Importance of Physiologically Balanced Solutions for Plants, 230.
Oohiea, 110.
Oolu, 110.
Opai, 110.
Opihi, 95, 96, 99.
Orthotrichum arcticum var. Blyttii, 299.
  Blyttii, 299.
  cancellatum, 299, 300.
  fenestratum, 299, 300.
Oscillatoria, 251, 254, 268, 270, 275, 279, 280.
  acuminata, 240.
  amphibia, 240.
  animalis, 240.

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Oscillatoria Bonnemaisonii, 240.
brevis, 240.
chalybea, 248, 259.
chlorina, 240.
curviceps, 240.
Froelichii, 251, 253.
geminata, 240.
imperator, 251.
laetevirens, 240.
limosa, 240, 250, 253.
margaritifera, 239, 259, 266, 272, 273, 279.
nigra, 251.
Okeni, 240.
proboscidea, 240.
tenuis, 240.
sancta, 240, 276.
simplicissima, 240.
splendida, 240, 250, 253, 266, 273.
Osmotic Pressure, in Marine Plants, Role of, 229.
Resistance of Certain Marine Algae to Changes in, 277.

Paakai, 104, 110.
Paakaiea, 110.
Padina Pavonia, 112.
Pahapaha, 110.
Pahapaha o Poli Hale, 111.
Pahee, 105, 111.
Pakaeleawa, 111.
Pakaeleawaa, 99.
Pakaiea, 100, 105, 110, 111.
Pakeleawaa, 111.
Palahalaha, 100, 111.
Palao, 105.
Palapahakou, 112.
Palawai, 105, 112.
Palewawae, 112.
Papaakea, 112.
Pehu, 112.
Peepee, 96, 112.
Pelagophycus giganteus, 149.
Pelea, 97.
Peltigera canina, 176.
Pelvetia, 157, 158.
Pepeiao, 112, 113.
Pepeulu, 113.
Perisporium agricola, 176.
Peziza hemisphaerica, 176.
Philonotis capillaris, 300.
fontana, 300.
fontana var. heterophylla, 300.
Phormidium, 251.
favosum, 240.
submembranaceum, 240.
uncinatum, 240, 276.
Phyllactinia fungicola, 176.
Phyllitis fascia, 116.
Pili-grass, 109.
Piliko'a, 113.
Pilipiliko'a, 112, 113.
Pinus pinaster, 177.
radiata, 177.
Pipilani, 113.
Plagiothecium neckeroides β myurum, 304.
undulatum var. myurum, 304.
Plocamium coccineum, 230.
Pogonatum alpinum, 303.
capillare var. dentatum, 303.
Poha, 113.
Polemoniaceae, Review of Californian, 1.
Index, 69.
Polytrichum gracile, 303.
strictum, 303.
yukonense, 303.
Populus, 206.
Porphyra naiadum, 230.
Postelsia palmaeformis, 149.
Post-embryonal Stages of the Laminariaceae.
Potassium on Magnesium, Antitoxic Action of, 235.
Prasiola Gardneri, 238.
Pseudhydnotria carnea, 169, 177, 178.
Harknessii, 169, 170, 171, 174, 177, 178.
Psilopilum arcticum, 303.
tschuctschicum, 303.
Pteridophytes, 315.
Pterosiphonia, 234.
bipinnata, 230.
Pterygophora, 158.
Ptilota, 234.
filicina, 230.
Puha, 113.
Pupukaneilio, 113.

Ratfoot, 96.
Reduplication, 215.
Regeneration among Kelps, 139.
Resistance of Certain Marine Algae to Changes in Osmotic Pressure and Temperature, 227.
Reversion, 214.
Review of Californian Polemoniaceae, 1.
Index, 69.
Rhacomitrium canescens, 298.
fasciculare, 298.
heterostichum, 298.
heterostichum f. stricta, 298.
lanuginosum, 298.
patens, 298.
Rivularia pisum, 251.
Role of Osmotic Pressure in Marine Plants, 229.
Ruppia, 230.
maritima, 229.
Russula, 176.

Digitized by Google

Saccorhiza bulbosa, 116, 118.
dermatodea, 117, 118, 152.
Salix, 206, 207, 209.
aurita, 207.
babylonica, 182, 200, 202, 210.
laevigata, 210.
lasiandra, 182, 200, 202, 215.
lasiandra X babylonica, 196, 202, 209, 210, 211, 214.
lasiolepis, 182, 184, 194, 196, 198, 202, 204, 205, 208, 209, 210, 211, 213.
Nuttalli var. brachystachus, 210.
purpurea, 187.
Salt limu, 104, 105, 110.
Sargassum, 101.
echinocarpum, 101.
Scleroderma, 176.
Scytonema Javanicum, 239.
Sea-lettuces, 105.
Slide Holder, 81.
Some Unreported Alaskan Sphagna, 309.
Spermosira litorea, 251.
Sphaeria, 178.
(Hypocrea) Setchellii, 169, 179.
Sphaeroderma episphaericum, 176.
Sphagnum acutifolium var. versicolor, 313.
Dusenii var. majus, 313.
fimbriatum var. concinnum, 313.
fimbriatum var. flavescens, 313.
fimbriatum var. robustum, 313.
fuscum var., 313.
Girgensohnii, 313.
Lindbergi var. macrophyllum f. fluitans, 314.
Lindbergi var. mesophyllum, 314.
medium, 314.
medium var. obscurum f. brachydasycladum, 314.
platyphyllum var. immersum, 314.
recurvum var. amblyphyllum, 314.
rubellum, 314.
squarrosum, 314.
squarrosum var. imbricatum, 314.
squarrosum var. subsquarrosum, 314.
subbicolor var. flavescens, 314.
teres var. imbricatum, 315.
Warnstorfii var. flavescens, 315.
Warnstorfii var. purpurascens, 315.
Spirogyra, 235.
Spirulina, 251.
major, 240.
subsalsa, 240.
Splachnum sphaericum, 300.
vasculosum, 300.
Squid, 95.
Staminody, 214.
Symploca Muscorum, 240, 247, 248, 273, 276, 280.
Synechococcus, 239.
Synechocystis, 280.
aquatilis, 239, 268, 280.
Synopsis of the North American Godetias, 319.
Index, 353.

Technique, Cytological, 73.
Temperature, Resistance of Certain Marine Algae to Changes in Osmotic Pressure and, 227.
Teratology in the Flowers of Two Californian Willows, 181.
Thalassiophyllum clathrus, 123, 125.
Tetraplodon mnioides, 300.
mnioides var. cavifolius, 300.
Tolypothrix, 254.
lanata, 250, 251, 254.
Tuber alba, 176.
puberulus, 176.
Turbinaria, 101.
ornata, 101.

Uaualoli, 113.
Ulaula, 113.
Ulota phyllantha, 299.
Ulva, 105, 112.
fasciata, 110, 111.
Utricularia, 157.

Vacuo, Fixation in, 78.

Wawaeiole, 96, 113.
Wawahiwaa, 113.
Webera cruda, 301.
proligera, 301.
Willow, 159.
Willows, Teratology in the Flowers of Two Californian, 181.

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BOTANY
Vol. 2, No. 15, pp. 317-318 October 22, 1907

ON NUTRIENT AND BALANCED SOLUTIONS

BY
W. J. V. OSTERHOUT

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ON NUTRIENT AND BALANCED SOLUTIONS

BY
W. J. V. OSTERHOUT.

The distinction between nutrient and balanced solutions depends on the fact that salts have two distinct functions, namely, nutritive and protective.[1] The nutritive function is too familiar to need discussion. The protective function is exercised when a poisonous salt has its toxic effect counteracted by addition of another salt, thus producing a balanced solution. The salt which is thus added for protective purposes need not have a nutritive value and may even, by itself, be highly poisonous. I have made experiments on various plants with substances of this kind with results which are for the most part of very striking character.

Among the principal salts of the soil those of magnesium are the most toxic. In a solution of .05 M $MgCl_2$ or $MgSO_4$ or $Mg(NO_3)_2$ grains of wheat make scarcely any growth. But if to a solution of 100 c.c. $MgCl_2$ .05 M we add 20 c.c. $SrCl_2$ a very fine growth is observed. The strontium has of course no nutrient value, but its protective value is very high in that it counteracts the poisonous effects of magnesium very effectively. On the other hand, barium, iron, and aluminum have practically no such action.

Sodium and potassium are quite toxic though less so than magnesium. If we place grains of wheat in NaCl (or KCl) .05 M very little growth occurs. The addition of a very small quantity of barium (100 c.c. NaCl .05 M + 1 c.c. $BaCl_2$ .05 M or 100

[1] Cf. Loeb, Dynamics of Living Matter, p. 77 ff., 1906.

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c.c. KCl .05 M + 1 c.c. $BaCl_2$ .05 M) at once produces a splendid growth. The barium is not only devoid of nutrient value but is by itself highly poisonous. In this case strontium acts very much like barium, but the addition of iron or aluminum produces very little effect.

The same substance may have both nutritive and protective functions. In the experiments just mentioned we could get as good or better protective effects by adding calcium instead of strontium or barium. Its protective action is very strong. But this action can only take place where there are toxic effects to be counteracted. In extremely weak solutions all these toxic effects disappear and then only the nutritive function of the calcium is exercised.

A nutrient solution may serve its purpose very well without being a balanced solution provided it be used in very dilute form. But if the concentration be increased we soon reach a point where toxic effects intervene, and these must be counteracted by addition of suitable protective salts. When this is done we have a balanced solution.

The classical researches of Pasteur and Raulin and the later work of other investigators have shown that calcium is not needed for the nutrition of fungi, and it is therefore omitted from culture solutions for these plants. This answers very well as long as the solutions are sufficiently dilute. I find, however, that when the concentration of the solution is increased it becomes toxic, and the addition of calcium then produces a remarkable improvement in growth. Calcium therefore has a protective value for fungi just as for other plants, though not needed for nutrition.

This illustration serves to show why the protective action of salts upon plants was not sooner discovered. Although the method of water culture has been employed for over two centuries, it has been the custom to use only very dilute solutions. For this reason the important facts regarding the protective action of salts, which are so striking in all except very dilute solutions, have been, until recently, completely overlooked.

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A SYNOPSIS OF THE NORTH AMERICAN GODETIAS

BY
WILLIS LINN JEPSON

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CONTENTS.

		PAGE
I.	History of the Genus	319
II.	Early Type Specimens	320
III.	Species in Godetia	321
IV.	Geographic Notes	321
V.	Hybrids	322
VI.	Field and Herbarium Work	323
VII.	Generic Diagnosis	324
VIII.	Key to the Species	324
IX.	Diagnoses and Critical Notes	325
X.	Little-known Species, Old and Recent	348
XI.	Index	353
XII.	Explanation of Plate	354

I.—History of the Genus.

The genus Godetia was published in 1835 by Edouard Spach in volume four of his "Histoire Naturelle des Vegeteaux. Phanerogames." The paper is entitled Monographia Onagrarieae, by which title it is often quoted. The genus was founded to receive the crimson-flowered species of Oenothera but has very slight technical validity, and differs from Oenothera mainly by habit, color of flowers, and the prismatic seeds which are margined at the chalazal end by minute teeth. Although segregated from Oenothera, Godetia is more nearly related to Clarkia and Eucharidium. Special evidence of this is seen in the species with 2-lobed petals, Godetia biloba and G. Blasdalei, and in the tooth-margined seeds. An interesting point of connection develops between

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Godetia Dudleyana, forma Brandegeae, which exceptionally shows a slender point in the notch of the petals and Clarkia Xantiana, in which the 2-lobed petals bear regularly a slender subulate point in the notch.

Notwithstanding its technical weakness Godetia as a genus has been approved by all authors who have been engaged in special studies on the California flora. Brewer and Watson give it place in the Botany of California, Greene in the Flora Franciscana, and Jepson in the Flora of Western Middle California, and it is also accepted in Engler and Prantl's Die Natürlichen Pflanzenfamilien. In favor of its retention it may be urged that the genus forms a group of species which is very compact, that it does not include doubtful species, and that its ecological characteristics. habitats, time of flowering and pollination devices, are exceedingly uniform.

II.—Early Type Specimens.

The earlier North American species were published mainly by W. Curtis, J. G. C. Lehmann, W. J. Hooker, John Lindley, and Edouard Spach. Hooker's and Lindley's diagnoses were founded mainly on Douglas specimens, which are preserved at the Royal Botanic Gardens at Kew, the British Natural History Museum at London and the Lindley Herbarium at Cambridge University. The sheets in the Herbarium Hookerianum at Kew, although not amply labeled as plants are labeled today, yet bear certain signs by which one familiar with Hooker's handwriting and herbarium methods may make positive identification of his types. The Godetia specimens in the Lindley Herbarium, although in good condition, do not bear, for the most part, any identification marks. The plants used by Spach are preserved at Paris in the Jardin des Plantes. In making transfers from Oenothera to Godetia it was the practice of this author to coin new specific names for all species taken over to the new genus. The Godetia synonomy, therefore, consists not merely of reduced species but an ample number of Spachian synonyms. Special discussion of all early types and early material to which I have had access will be found under each species in the body of the text.

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III.—"SPECIES" IN GODETIA.

The North American species fall into two groups, the loosely flowered freely branching plants or Amoena group, and the spicately flowered simple stemmed forms or Purpurea group. Both groups, especially as represented by their dominant types, are exceedingly variable, at least in the sense that each presents a large number of forms. The Amoena group includes about one hundred and seventy-five forms; the Purpurea group about twenty-five forms. There is no doubt that those who recognize the maximum number of species in Eschscholtzia and in Platystemon will some day describe two hundred species in Godetia. It is interesting in this connection to note that some of the early species like Godetia decumbens and G. Romanzovii, described nearly a century since from plants grown from seed, have varied in the slightest degree in cultivation. These species are, to me, not known wild, but the garden specimens at whatever time they have drifted into the European herbaria since the beginning of the 19th Century and often separated by many generations are promptly recognized.

On the other hand the thesis that there are but two distinct species in the genus as represented in North America could be vigorously and ably defended. The author of this paper has, however, chosen to recognize seventeen species, representing the types which morphologically and geographically are sufficiently marked for purposes of geographic studies or taxonomic comparisons and which by their character serve to give a satisfying idea of the richness of form in this group of Pacific Coast plants. It may be said that there are, in addition, some recently published species, of which material has not been available. Although noticed at the end of the paper, a full discussion of them must be reserved for a future time.

IV.—GEOGRAPHIC NOTES.

The genus Godetia in North America is confined to the Pacific Coast and has its greatest development in California.[1] A few

[1] Citations of localities in this paper should be understood as referring to California unless otherwise stated.

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species range north into Oregon and reach British Columbia, and one or two range into Lower California.

The groups of Godetia differ considerably viewed from the standpoint of geographical distribution in California. Godetia amoena and its immediate allies are fairly well defined geographically. Godetia Bottae, which occurs from the Monterey region southward, replaces Godetia amoena which covers the coast region north. The former follows the cross ranges of Tehachapi in modified forms into the southern Sierras. Another ally is G. viminea which keeps to the Sierra Nevada Mountains, ranging north into Oregon. I have seen no genuine Godetia amoena from the Sierras. Godetia Dudleyana, G. Hanseni, and G. arcuata are almost wholly Sierran and, so far as known, with exclusive areas. Godetia biloba, which is extensively distributed throughout the Sierras, recurs in the Contra Costa region of the Coast Ranges. The extreme variants of the Godetia amoena aggregate are therefore more or less separated geographically.

The Godetia quadrivulnera aggregate, on the contrary, is widely distributed in both the Coast Ranges and Sierra Nevada, extending northward to Washington. It breaks into numerous forms, usually of a similar character, repeatedly throughout its range, and has a very great biologic interest on this account. The lower leaves are thin and plane; late in the flowering period on the approach of the dry season the later upper leaves become thicker and trough-like or half-conduplicate.

The densely spicate forms, Godetia purpurea and Arnottii, are characteristic of hot valleys, the Great Valley or those of the south Coast Ranges; they grow on the valley level, often in the dried beds of vernal pools. These species also lose their lower leaves early, and by fruiting time bear only bracteal leaves which are broader and thicker than the earlier leaves. Godetia grandiflora seems to be peculiar to the coast region of Sonoma and Mendocino counties.

V.—HYBRIDS.

Field and herbarium studies on the variations in this group of plants continually suggest to the author that part of these may be due to hybridization. Opportunity for experimental work under control has not yet presented itself, but the observations of

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two other workers may, in passing, be mentioned. Mrs. K. Brandegee, who has a great interest in transition and exceptional forms and has collected a number of such in Godetia, discovered between Martinez and Port Costa in July, 1907, a plant believed by her to be a hybrid between Godetia biloba and Clarkia elegans. The form of the petals is singularly variable even on the same flower. (See Plate 29, figs. 10-14.) The 2-lobed petals are like Godetia biloba, the 3-lobed ones recall those of (to the mind of the author) Clarkia concinna. The plant produced capsules. Godetia Dudleyana, forma Brandegeae is, possibly, a hybrid between that species and Godetia biloba. The petals show every stage from the entire petals of the former to the deeply notched type with narrow lobes of the latter.

The experience of Mr. Carl Purdy may also be mentioned. He is cultivating on a considerable scale the more showy forms of West American Godetias and tells me that natural hybrids are freely produced in his garden.

VI.—Field and Herbarium Work.

Botanical expeditions during the last fifteen years have given the author opportunity to study and collect a rich series of Godetia forms from all parts of the Coast Ranges and Sierra Nevada. Studies of variation in the field, with notes upon the living plants, have provided a useful store of notes for this paper. In addition the material of others as gradually acquired by the University of California Herbarium has been the subject of examination.

The investigation of types in European herbaria was undertaken in 1905 and 1906, the material at the Kew Herbarium,[2] British Natural History Museum, University of Glasgow Herbarium, University of Cambridge Herbarium, Berlin Herbarium, and Paris Herbarium were visited. On account of the richness of the collections and library facilities at Kew, this paper was mainly elaborated at that institution.

For the privileges of an investigator and for many helpful courtesies I am happy to express my obligations to the following:

[2] The herbaria of W. J. Hooker ("Herbarium Hookerianum") and of Geo. Bentham ("Herbarium Benthamianum") were acquired by the Royal Botanic Gardens at Kew and have been incorporated with the general Kew Herbarium.

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Colonel David Prain, Director of Royal Botanic Gardens, Kew, Surrey; William Botting Hemsley, Esq., Curator of the Herbarium, Royal Botanic Gardens, Kew; the late Professor Marshall Ward, Cambridge University, in charge of the Lindley Herbarium; Dr. A. B. Rendle, Sir James Britten, and E. G. Baker, Esq., Department of Botany, Natural History Museum, London; Dr. W. H. Lang, University of Glasgow, Scotland; Dr. Adolf Engler, Director, and Dr. I. Urban, Vice-Director, Royal Botanic Gardens, Berlin; M. F. Gagnepain, Botanic Garden, Paris.

VII.—GENERIC DIAGNOSIS.

GODETIA SPACH.

Mostly erect annuals with narrow shortly petioled or sessile alternate leaves. Flowers showy, red, crimson, purple, cream-color or nearly white, opening during the day, disposed in leafy racemes or spikes, the inflorescence sometimes reduced to but few flowers or a single one. Calyx often colored; calyx-tube obconic or funnelform. Petals 4, commonly broad and entire, sometimes notched or 2-lobed. Stamens 8, those opposite the petals shorter; anthers basifixed. Capsule linear, rarely ovate, 4-sided or terete, mostly longitudinally ribbed, 4-celled, 4-valved. Seeds in 1 or 2 rows, more or less cubical or elongated, often obliquely pointed at one end, the opposite end more or less obliquely truncate, chalaza central and the edges margined.

VIII.—KEY TO THE SPECIES.

A.—*Capsule not ribbed or indistinctly so, terete or teretish.*

Flowers loosely spicate-paniculate; capsules shortly attenuate at apex..... .....1. *G. amoena.*

Flowers spicate or on short slender branchlets of the single main stem; capsules thick, blunt at apex ..... *G. Blasdalei.*

Flowers spicately scattered.

Buds nodding; calyx lobes remaining united and turned to one side under the open flower.

Coast Range species; stigmas partly united so as to form a saucer-shaped or shallowly cup-shaped base.

Ovary often curved before anthesis; inflorescence usually very loose; capsule typically with flat sides.....3. *G. Bottae.*

Ovary straight and deflexed before anthesis; flowers in a closer spike .....4. *G. deflexa.*

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Sierra Nevada species; stigmas distinct.
Petals 2-lobed.....5. *G. biloba.*
Petals not lobed.
Calyx-tube without annular process.
Capsule sessile or subsessile, not at all or scarcely beaked; style no longer than stamens .....6. *G. Dudleyana.*
Capsule long-pedicelled and long-beaked; style much longer than stamens.....7. *G. arcuata.*
Calyx-tube with an annular swelling at summit of ovary.....8. *G. Hanseni.*
Buds erect.
Calyx-lobes commonly distinct and closely reflexed.
Tube of calyx long (5 to 11 mm.).
Erect; capsules straight or nearly so; Sierra Nevada.....9. *G. vimineа.*
Diffuse; capsules curving; Coast Range.....10. *G. parviflora.*
Tube of calyx short (2 to 3 mm.).
Capsule long and slender, not strongly ribbed; spikes usually long and flowers scattered.....11. *G. quadrivulnera.*
Capsule short and thick, strongly ribbed, hairy; spikes short or at least not loose.....12. *G. Goddardi.*
Calyx-lobes united and turned to one side under the open flower; capsule pedicellate.....13. *G. epilobioides.*

B.—*Capsule 8-ribbed (the ribs on the lateral faces sometimes indistinct), more or less 4-sided.*

Flowers in dense clusters.
Petals 1 to 2.2 cm. long.
Stems regularly leafy.
Ovary hairy; petals pale crimson with a dark blotch at apex, 1 to 2.2 cm. long.....14. *G. purpurea.*
Ovary glabrous; petals rose-red, without blotch, 1.3 cm. long.....15. *G. Arnottii.*
Stem interruptedly leafy; petals purplish with a spot toward summit, 1 cm. long .....16. *G. sparsiflora.*
Petals large, 4 to 4.5 cm. long; north coast of California.....17. *G. grandiflora.*

IX.—DIAGNOSES AND CRITICAL NOTES.

1. **G. amoena** Lilja.

Erect, simple or more commonly branching, 2 to 7 dm. high; leaves linear to lanceolate, narrowed at base to a petiole or sessile, 1 to 8 mm. broad, 1 to 5 cm. long (or with smaller ones fascicled in the axils), the uppermost half-conduplicate and curved; buds erect, rarely drooping; calyx-lobes united and turned to one side in anthesis but usually distinct at base, less commonly wholly

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distinct, 1.4 to 2.3 cm. long, their tips not free in the bud; calyx-tube 5 to 10 mm. long; petals lilac-crimson or red-pink, often with a darker central splotch or base, abruptly narrowed to a short claw, 1.7 to 2.3 cm. long, usually twice the length of the stamens; anthers crimson, upper end yellow, coiling after dehiscence, 6 to 8 mm. long; filaments (at least of the shorter stamens) shorter than the anthers; stigmas yellow, linear, 3 to 6 mm. long; ovary canescent, sessile or very shortly pediceled; fruit teretish, not ribbed, tapering very slightly to each end, 3.5 to 4.5 cm. long, on pedicels 0.3 to 1.7 cm. long. (Pl. 29, fig. 19.)

Near the coast from Monterey Co., northward to British Columbia: Gabilan Range; Santa Cruz Mts.; Mission San José, *Setchell and Jepson*, 1896; Morrison Cañon, Niles, *W. L. J.*, June, 1897; Oakland Hills; Mt. Tamalpais, *W. L. J.*, June 19, 1891; York Creek, Napa Valley, *W. L. J.*, no. 2429; Howell Mt., *W. L. J.*, 1893; Three Creeks to Willow Creek, *W. L. J.*, no. 2126, and northward to British Columbia. It is very common and very showy on shady banks or hillslopes in the San Francisco Bay Region and has the most extensive range of any species in the genus and exhibits great variability, especially in the size and color-schemes of the flowers. This variability is most pronounced away from the immediate neighborhood of the sea in the Coast Ranges where reduced individuals with few and small flowers prevail; the petals but 0.7 to 1.5 cm. long. A curious form with the petals 1 cm. long and exserted style was collected at Cloverdale in 1877 by Sir Joseph Hooker and Dr. Asa Gray. In the Shasta region and southward local variations appear quite to the exclusion of typical amoena, though weak in individuals.

Of all species of our Godetias, G. amoena is most obscure as to the origin of the original material. Lehmann described the species from plants first grown in the Botanic Garden at Hamburg in 1820, the seeds having been received in 1819 from North America. The first description is as follows:

"O. pubescens, caule herbaceo tereti purpurascente, foliis lanceolatis obtusiusculus subdentatis glaucis, petalis calyce triplo longioribus, capsulis subteretibus. Hab. in America septentrionali. [Annual]."—Ind. Sem. Hort. Hamburg, 1821. p. 8.

The above description is not from the 1821 seed list but from

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the reprint in the 1824 list. The name amoena antedates O. roseae, O. roseo-alba, etc., of Lehmann.

In 1828 Lehmann published a full description in "Index Scholarum," p. 22 (1828), being a pamphlet, "Pugillus Primus." of his "Novarum et Minus Cognitarum Stirpium," and generally quoted as "Pugill. Plant. Nov." The description is in Pugillus I, p. 22, as follows:

"Caulis herbaceus, teres, canescens, simplex, erectus, ½-1 pedalis, basi fuscus, apice e viride purpurascens. Folia alterna, crassiuscula, lanceolata, obtusiuscula, remote-denticulata vel integerrima, glauca, breviter petiolata ½-1″ longa, 3-6‴ lata. Flores 1-3 in summo caule axillares, breviter pedicellati. Calyx infundibuliformis, pubescens: laciniis lineari-lanceolatis, reflexis, apice fusco-callosis, intus glaberrimus, extus pubescentibus saepe cohaerentibus, basi tantum distinctis. Petala ampla, late-obovata, subemarginata, basi cuneata, a medio ad apicem undulato-crenata, alba basi rosea, inferne macula striata purpurea subtriangulari instructa. Stamina calyci inserta, plana, subulata, rosea, petalis breviora; antherae incumbentes, subulatae, subcurvatae: polline filamentoso. Stylus filiformis, albus, stamina superans: stigmatibus 4 semi-cylindricis. Germen cylindricum, 4 sulcatum, canescens. Capsula 1-1½ pollicaris, subtetragona, quadri-sulcata, curvula, pubescens.

"*Obs.* Semina hujus insignis speciei liberalitate amplissimi Senatoris H. J. Merck, cui hortus noster multas easque pulcherrimas plantas debet, primus anno 1819 ex America septentrionali sine nomine cum aliis seminibus accepimus. Paucis annis post semina quoque illius sub nomine Oenotherae rosae ex horto botanico Kiloniensi nobiscum communicata sunt. Eadem serius ex diversis hortis nobis missa est sub nomine Oenotherae roseo-albae. Proximis annis planta formam supra descriptam referebat, postea vero sensim ita mutata est, ut non solum duplo major, sed etiam ramosior et multiflora facta sit."

In 1829, in the Nova Acta Physico-Medico Academiae Caesareae Leopoldino-Carolinae Naturae-Curiosorum," Lehmann reprinted almost verbatim the above description. The reference is: Nov. Act. Nat. Cur. vol. 14, p. 811. But there is added a colored drawing, representing a small plant blooming in the juvenile

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period with nearly white flowers and with leaves as broad as those in a seedling and not seen on flowering plants of the California amoena.

I find in the Kew Herbarium a plant, similar to the one illustrated, which Lehmann sent to W. J. Hooker at Kew. The label reads "Ind. Seminum 1820 collectorum cum diagnosi." Hooker wrote on the label "Lehmann." This plant was evidently from the original lot of seeds: it corresponds with the drawing published by Lehmann save in having only one flower. I describe it as follows:

Plant 1.2 dm. high; little cluster of leaves below the ovary ovate or mainly oblong, tapering upwards, 1 to 1.6 cm. long, including short petiole; calyx-tube 5 mm. long; sepals united and turned to one side; petals 2.2 cm. long; stamens 6 and 9 mm. long, short and long respectively; anthers 2 mm. and 3 mm. long; style beyond calyx-tube 1.3 cm. long; stigmas long and slender (4.5 mm. long), slightly exceeding the stamens; ovary 1.8 cm. long, including the short pedicel which is difficult to differentiate.

The usual form of Godetia amoena in the Oakland Hills I take to be indistinguishable from type. The anthers in the Oakland Hills plants are 8 mm. long, curling promptly at the upper end or becoming sickle-shaped. In Lehmann's plant they are very short but show a disposition to curl at the upper end; they are basifixed, not versatile as shown in his illustration. The seed, if coming from California at all, most likely came from the San Francisco-Monterey region. My no. 2020, Martin's Ranch, South Fork Trinity, matches type well, especially in size of flowers and length of stamens and style. The Martin's Ranch plant is somewhat depauperate, which perhaps accounts for the very close resemblance in all parts.

Var. **concolor** Jepson, Fl. W. Mid. Cal. p. 334 (1901). Simple 2 to 3 dm. high; leaves narrowly linear; sepals united and turned to one side; petals 1 to 1.5 cm. long, uniform crimson.—Pope Valley Grade.

Forma **pygmaea** Jepson, n. form. Very slender, unbranched, 1 to 3 dm. high, all the parts small; petals crenulate, often abruptly acute, 5 to 10 mm. long, usually with central blotch.—Conn Valley, dry hills, *W. L. J.*, May 1, 1894.

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Var. **albicaulis** Jepson, n. var. Stems white shining, simple or strictly branched, 5 dm. high; leaves narrow; petals 3 to 4 cm. long; capsule about 4 cm. long, with a beak usually 1 cm. long.—Rancho Chico, *Mrs. Bidwell,* May, 1878, no. 122; *Fremont,* no. 435, 1846,—both Kew Herbarium.

Forma **Huntiana** Jepson, n. form. Very diffuse and widely branching, 4 to 8 dm. high; flowers small, 1 to 1.4 cm. long; petals crimson with a mostly 3-forked blotch in the center.—Blue Lakes, July 16, 1897, *W. L. Jepson & L. E. Hunt;* Saratoga Springs, *W. L. J.*, 1892.

Var. **Lindleyi** Jepson, n. comb. *Oenothera Lindleyi* Douglas. Petals 2 to 3.5 cm. long, almost uniformly with a large central blotch.—Common in the North Coast Ranges, near the sea, Capetown, *W. L. J.*, no. 2141; Three Creeks to Redwood Creek, 4000 ft. alt., *W. L. J.*, no. 2130, and northward to British Columbia.

Refs.—GODETIA AMOENA Lilja, Linnaea, vol. 15, p. 265 (1841); Brewer & Watson, in Bot. Cal., vol. 1, p. 230 (1876); Greene, Fl. Fr. p. 222 (1891); Jepson, Fl. W. Mid. Cal. p. 333 (1901).

Oenothera amoena Lehmann, Ind. Sem. Hort. Hamburg, p. 8 (1821); Pugill. Plant. Nov., pt. 1, p. 22 (1828); Nov. Act. Nat. Cur., vol. 14, p. 811, t. 45 (1829); Torrey & Gray, Fl. N. Am., vol. 1, p. 503 (1840); Watson, Proc. Am. Acad., vol. 8, p. 599 (1873).

Oenothera Lindleyi Douglas; Hooker, Bot. Mag. t. 2832 (1828). Type specimen in Kew Herbarium labeled thus: "Oenothera Lindleyi. Common on the N.W. coast. Fort Vancouver. Multonomah river mei. D. [Douglas]." There are two plants, the lower portions of each broken off, 4.2 dm. high, little branched, virgate; herbage puberulent; leaves lanceolate, petioled, 4 cm. long, smaller ones fascicled in axils, the larger running to the conduplicate style; calyx-tube 5 mm. long; calyx-lobes united and turned to one side, distinct only at very base, tips not free in bud; petals 2.3 to 3 cm. long (color quite gone); stigmas very slender, 4 mm. long; capsule 3 cm. long, teretish, not obviously furrowed, minutely pubescent, although in description (from garden plant?) Hooker says "glabrous"; pedicel 1 to 2 mm. long.

This specifically equals G. amoena, the Californian form nearest Lindleyi being the 4-spotted plant of the north coast, the

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only difference being the tendency of the latter to diffuseness in habit. Godetia Lindleyi as shown by early Oregon specimens (*Tolmie, Douglas*) has either sessile or (4-8 mm. long) pedicelled capsules.

Oenothera roseo-alba Bernhard, Ind. Sem. Hort. Erfurt. (1824). Figure in Reichenbach, "Iconographia Botanica Exotica," or "Hortus Botanicus," pl. 47, shows a seedling-like plant in flower, the counterpart of Lehmann's figure; the anthers are shown basifixed, however. It plainly equals G. amoena. Pl. 150 shows a flower branch 7 inches long flowering prolifically (about 50 flowers!).

Godetia rubicunda Lindley, Bot. Reg., t. 1856 (1836). This, a Douglas plant, must have been collected between Monterey and Sonoma. It is a color form of G. amoena.

Godetia vinosa Lindley, Bot. Reg., t. 1880 (1836), another Douglas plant, is a white-flowered form. It shows correlated variation in that the ends of the anthers are white, corresponding to the petals. The characters given by Lindley as distinctions between *vinosa* and *rubicunda* rest upon plainly variable parts.

Godetia viminea Parsons, Wild Fls. Cal., p. 240, ill. (1897), not of Spach.

2. **G. Blasdalei** Jepson, n. sp.

Erect, often stout, simple or with slender short strict branches, 6 to 8.5 dm. high the stem soon leafless except above; leaves oblong to linear-lanceolate, acute, 3 to 4.5 cm. long; herbage puberulent; flowers essentially like those of the large-flowered form of G. amoena, but petals notched at apex or even deeply bilobed; ovary thick below middle, tapering to base and also to apex something like a rifle cartridge; capsules canescent, thick, terete, rather short (1.3 to 2 cm. long), on pedicels 2 to 5 cm. long.

San Francisco Bay Region: Point Isabel, July 11, 1893, *Dr. W. C. Blasdale;* Oakland, July, 1865, *Bolander; Douglas,* 1831-2, perhaps in the same region.

3. **G. Bottae** Spach.

Slender, erect, simple or more commonly branching at or from the base, 3 to 7 dm. high; leaves linear or lanceolate, or the lower oblong, remotely denticulate, petioled or sessile, .5 to 7 mm. broad,

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1.5 to 5.5 cm. long; flowers axillary but falsely terminal through usurpation, the growing capsules thrusting the shoot to one side so that the latter seems proliferous; buds nodding, slender ovate, abruptly tipped with a slender short point; calyx-tube very short, 2 to 3 mm. long; calyx-limb turned to one side with the lobes united in anthesis, commonly crimson-tinted, 10 to 19 mm. long; petals pink or light crimson, 1.6 to 2.6 cm. long; stamens 12 to 17 mm. long, equaling the styles; stigma deeply parted into 4 oblong or elliptic lobes but united at base so as to form a swollen somewhat cup-shaped apex to the style; capsules scattered, rather distinctly 4-sided with the plane sides not at all ribbed or obscurely so, a trifle less than 2 mm. broad, 2.3 to 3.3 cm. long, on pedicels 1 to 3 cm. long; seeds all over minutely granulate.

South Coast Ranges: Pajaro Sand-hills, *Chandler,* no. 450; Monterey, State Survey, 701, *Guirado* (not Brewer); Santa Lucia Mts., *W. L. J.,* no. 1685; San Luis Obispo, *Barber, Summers;* (?) "Santiago Cañon," Southern California, *Blasdale.*

Spach's measurements in the original description are for the most part too great for any North American Godetia save G. grandiflora, which is out of question. He speaks, however, of the long pedicels three times which is a characteristic feature of the species. His type is preserved at the Jardin des Plantes, Paris. One specimen is labeled by Spach as follows: "Godetia Bottae nob. (Spach, 1839), Californie, M. Botta." The other he labeled "Godetia Bottae Spach," and in another hand on the same label is the legend, "Monterey, M. P. E. Botta, 1829."

I describe type specimens as follows: Herbage not obviously pubescent; leaves narrowed to a petiole-like base, 5 mm. wide, 7 cm. long (extreme measurements), obscurely and remotely denticulate; one bud nodding, the other ascending, abruptly pointed; petals 2.7 cm. long, 2.1 cm. broad, truncate; calyx-segments united and turned to one side; calyx-tube about 2 mm. long; ovary slender, linear, barely canescent; stigmas broadly oblong, united at base, 2 mm. long; pedicels 1 to 1.5 cm. long or almost none. I regard my Santa Lucia Mountains specimen, no. 1685, as a good match for the type specimens.

M. P. E. Botta, who first collected it, was a traveler of the Natural History Museum of Paris and made a voyage of circum-

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navigation in the years 1827-29 on board a trading vessel, "le Heros." He was mainly a collector of reptiles.

Towards the south and in the southern Sierras G. Bottae becomes distinctly variable. The following varieties are to be noted:

Var. **usitata** Jepson n. var. Stigma short-oblong or quadrate; capsule commonly sessile or nearly so, thick, rather obviously 8-ribbed.—Southern California; rather common. San Bernardino, *Parish*, no. 3672.

Var. **cylindrica** Jepson n. var. Nearly or quite simple, 1.8 to 3.8 dm. high, few-flowered; leaves narrowly linear or subfiliform, 0.5 to 1 mm. broad; calyx indigo-purple; petals 1.9 to 2.2 cm. long, lilac-purple above, paler with a sprinkling of dark dots, at base with a dark purple band; anthers sometimes purple-dotted; capsules slender (scarcely more than 1 mm. broad), teretish, not costate, as much as 3.2 cm. long, sessile (or sometimes with a pedicel 7 mm. long!).—Warthan Creek near Alcalde, *W. L. J.*, no. 2656A; San Emigdio Cañon, *Davy*, no. 1992; Clark's Valley to Squaw Valley, Fresno Co., *W. L. J.*, no. 2746; Fort Tejon, Kern Co., *Hall*, June 17, 1905; Blue Mt., Greenhorn Range, Kern Co., *Hall & Babcock*, no. 5007; Bakersfield, *Davy*, no. 1713.

Refs.—GODETIA BOTTAE, Spach., Nouv. Ann. Mus. Hist. Nat., vol. 4, p. 393 (1835); Brewer & Watson, in Bot. Cal., vol. 1, p. 231 (1876); Greene, Fl. Fr., 222 (1891).

Oenothera Bottae, Torrey & Gray, Fl. N. Am., vol. 1, p. 505 (1840); Watson, Proc. Am. Acad., vol. 8, p. 599 (1873).

4. **G. deflexa** Jepson, n. sp.

Substrictly branching or simple, 2 to 5 dm. high, the stem more or less twisted or flexuous; leaves thickish, narrowly oblong, some tapering to the apex, shortly petioled, 2 to 8 mm. broad, 3 to 6 cm. long, remotely denticulate, the teeth minute but more or less salient; herbage almost glabrous; flowers spicate; calyx-buds large, 2.8 cm. long, before anthesis borne on abruptly deflexed sessile ovaries; calyx-tip not free in bud, the united lobes turned to one side under the open corolla; petals lilac, sprinkled with crimson dots, cuneate-obovate, abruptly short-clawed, truncate or even shallowly retuse at the summit, 2.5 to 3 cm. long; stamens subequal, nearly or quite one-half the length of the petals; style

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usually exceeding stamens; stigma peltate or somewhat saucer-shaped, undulately 4-lobed; ovary slender, white with fine short hairs; capsule apparently 4-sided but mature fruit not known.

"Sandy plains of Los Angeles," W. Lobb, 1854(?). Elmer, no. 3848, Gaviota, is, perhaps, the same. Differs from G. Bottae in its stouter main stem, and in the strictly lateral deflexed pods which do not usurp a falsely terminal position. Lobb's specimen is at Kew.

5. **G. biloba** Watson.

Freely branching, 4 to 6 dm. high, or on poor soil or in exposed situations frequently simple and less tall; leaves oblong-lanceolate, entire or obscurely and remotely denticulate, the lower on long slender petioles, 1.5 to 5.5 cm. long; buds nodding, narrowly ovate, commonly abruptly tipped with a slender point; calyx-lobes united and turned to one side in anthesis, purplish-brown, 9 to 15 mm. long, the tips not free in the bud; petals broadly cuneate, with emarginate, cleft or with a deep v-shaped notch at apex, 0.9 to 2.4 cm. long; capsule 4-sided, weakly 8-ribbed, 1 to 1.3 mm. broad, 1 to 1.5 (2.3) cm. long, on pedicels 1 to 2 mm. long; calyx-tube with a dense ring of short white hairs at the mouth; all filaments longer than anthers or those of short stamens shorter than anthers. (Pl. 29, figs. 3, 9.)

Sierra Nevada Foothills, 1500 to 2000 ft.: Greely Hill above Coulterville, *W. L. J.*, 1896; Coloma, *Edw. Palmer*, no. 2388; Colfax, *M. E. Jones*, no. 3340; Mt. Bullion, *Bolander;* Mokelumne Hill, *Rattan;* New York Falls, Amador Co., *Hansen*, northward to Butte Co., *Hartweg*. Also in Contra Costa County from Antioch to Crockett, *Tidestrom*, 1895. I take as type the usual form in which the lobes of the petal are narrow and divergent, the outline of the petal being strongly suggestive of a bootjack.

Refs.—GODETIA BILOBA Watson, in Bot. Cal., vol. 1, p. 231 (1876); Greene, Fl. Fr., 222 (1891); Jepson, Fl. W. Mid. Cal., p. 333 (1901).

Oenothera biloba Durand, Pl. Pratt., p. 87 (1855); Watson, Proc. Am. Acad., vol. 8, p. 599 (1873).

6. **G. Dudleyana** Abrams.

Slender, simple or with rather strict branches above the

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middle, less commonly from the base, 2 to 7.5 dm. high, puberulent or the older parts glabrous; leaves filiform to oblong, entire or remotely denticulate, petioled or sessile, 1.5 to 6 cm. long, 0.5 to 5 mm. broad, conduplicate upper leaves few or none; buds slender, ovate, often abruptly attenuate near apex, nodding, the tips of the calyx lobes not free; calyx purple to lavender, turned to one side in anthesis, 1 to 2 cm. long; petals pink-crimson with crimson dots in center, 1.2 to 2.6 cm. long; stamens as long as the style, the anthers contracting and coiling after anthesis; filaments all or only those of the short stamens purple; anthers yellow, 4 to 7 mm. long; style purplish, stigmas linear to oblong, 0.5 to 2 mm. long; capsule slender, sessile or nearly so, 2-ribbed on each face, 1.3 to 2.1 cm. long; ovary slender ovate, 8-grooved, weakly hispidulose. (See pl. 29, fig. 16.)

Sierra Nevada Mts., 2500 to 4000 ft., on barren hillslopes or open places in brush or woods: Greely Hill, above Coulterville, *W. L. J.*, July, 1896; Halstead's Ranch, Kaweah, *W. L. J.*, no. 573, alt. 2000 ft.; Cedar Creek, North Fork Kaweah, *W. L. J.*, no. 614, alt. 4000 ft.; Yosemite Valley, *W. L. J.*, 1896; Tuolumne River, *Blasdale*, May 20, 1895; (?) Fresno Co., foothills, *Hall & Chandler*, no. 10, June 13, 1900; Kaweah River, *Coville & Funston*, 1320; Kaweah, *Ralph Hopping*, May 3, 1901; Middle Tule River, *Purpus*, no. 5036; (?) Reche Cañon, San Bernardino Co., *H. M. Hall*, no. 1105. Also collected in the Sierra Nevada by "Fremont, Ppp. 1846," *Bolander*, 6366, and *Bridges*, no. 80, the last undoubtedly in the Yosemite region.

G. Dudleyana and G. Bottae may run too close to each other. In general G. Dudleyana has an 8-grooved very narrowly ovate ovary; G. Bottae has a narrowly linear ungrooved ovary.

I have not seen authentic specimens of G. Dudleyana Abrams, Fl. Los Angeles and Vicinity, p. 268 (1904), the type locality of which is Little Santa Anita Cañon at 2500 feet altitude. The above diagnosis rests in the first instance on my specimens from Greely Hill and Cedar Creek, which have long lain in my working collection under the manuscript name of G. jucunda, a name which may be taken up if G. Dudleyana will not include the Sierra plants.

Forma **Brandegeae** Jepson, n. form. Petals broad, mostly 1

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to 2 cm. broad, shallowly notched.—Simpson's Ranch, Sweetwater Creek, El Dorado County, *Mrs K. Brandegee,* May 29, 1907. Petals exceedingly variable in notching, exceptionally with a slender point in the notch. It may be a hybrid between the species and Godetia biloba. (Pl. 29, fig. 7.)

7. **G. arcuata** Jepson, n. comb. *Oenothera arcuata* Kellogg.

Slender, 2 to 5½ dm. high, sparingly branched, more or less falsely dichotomous on account of the repeated divergence of axis and branch; leaves linear, entire, 3 to 5 cm. long, 2 to 3 mm. broad, obtusish, the fascicled and upper leaves 5 to 6 cm. long, narrow (1 to 2 mm. broad), commonly conduplicate and appearing much narrower, more or less arcuate curving, with long slender acute tips; flower buds large, ovate acute, 2 to 2.5 cm. long; calyx-tube 4 to 6 mm. long, often purple inside, the lobes remaining united and turned to one side; petals flabelliform, lilac, 2 to 3 cm. long, 1.2 to 2.6 cm. broad, usually retuse at the more or less truncate apex; anthers 4 to 8 mm. long; style much longer, often twice longer than stamens; stamens yellow, linear, 2.3 to 3.5 mm. long; ovary hispidulose with short spreading hairs of unequal length; capsule 8-ribbed, the ribs separated by broad sharply defined channels, those opposite the partitions broader, about 2.5 cm. long, with a beak 5 or 6 mm. long and borne on a pedicel 5 to 10 mm. long; seed 1 mm. long, sharply pointed at one end, the other end obliquely flattened and with a thin margin. (See pl. 29, figs. 5, 17, 20, 26.)

Local in the Sierras of El Dorado County: American River, Apr. 27, 1898, comm. by Miss Alice King; near Placerville, *Mrs. K. Brandegee,* May 25, 1907, which is the type locality for Kellogg's Oenothera arcuata, Proc. Cal. Acad., vol. 1, p. 58 (1855). I also include with slight uncertainty the following: Harmon Peak, Calaveras Co., *Davy,* no. 1407, May 18-30, 1895; Sherlocks, Mariposa Co., *Congdon,* May 3, 1898.

Refs.—OENOTHERA ARCUATA Kell., Proc. Cal. Acad., vol. 1, p. 58 (1885).

Godetia hispidula Watson, Proc. Am. Acad., vol. 8, pp. 599, 609 (1873). Watson in citing specimens mentions first Fremont's nos. 307 and Ppp. Part of the no. 307 as seen by me at Kew, that is, the specimen with long-pedicelled and beaked squarish capsule with 2 sides flattish or very shallowly grooved, I include under

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G. arcuata. The other specimen and the specimens under "Ppp," I refer to Godetia Dudleyana. The dried pods in all specimens appear squarish or 4-sided, with two opposite sides each 2-ribbed, the other sides smooth or indistinctly 2-ribbed.

8. **G. Hansenii** Jepson, n. sp.

Plant very slender, sparingly branched, 0.8 to 2.4 cm. high; herbage puberulent or the stem glabrous; leaves narrowly linear (1 to 2 mm. broad), acute or long acuminate, entire and sparsely or obscurely denticulate, 2.5 to 4 cm. long, subsessile or shortly petioled; buds at an early stage nodding but soon erect, the calyx-tips not free; flowers few, scattered in the upper axils; sepals in anthesis remaining united and turned to one side; calyx-tube narrowly vase-shaped, 6 or 7 mm. long, with a distinct annular swelling at summit of the ovary; ovary apparently glabrous, but sparingly covered with minute short spreading gland-tipped hairs, inversely clavate, 1 to 1.5 cm. long, and borne on pedicels 2 to 7 mm. long; long stamens about half the length of the petals; style nearly as long as petals, the stigmas whitish, elliptic-oblong; young capsules 1.3 to 2 cm. long including the marked beak which is 2 to 6 mm. long; lateral faces of capsule with a very shallow furrow sloping to center, the other faces with 2 or 3 filiform ridges; stipe 1 to 3 mm. long.

Armstrongs Station, Amador Co., 5000 ft., *Hansen*, no. 1090, in 1895. Type in the Kew Herbarium, a fruiting specimen in the Berlin Herbarium.

9. **G. viminea** Spach.

Stems whitish and shining or sometimes reddish above, strictly erect and simple or with simple suberect branches, commonly 3 to 9 dm. high, but often dwarfish and only 0.5 to 1 dm. high; herbage finely pubescent, the older parts of the stem glabrescent; leaves linear to lanceolate, entire, narrowed at base to a short petiole or the upper sessile and commonly conduplicate, 0.5 to 5 cm. long; buds erect; calyx-tube broadly vase-shaped or narrowly campanulate, whitish membranous, 6 to 11 mm. long, 3 to 5 mm. broad at apex; calyx-lobes lanceolate, acuminate, distinct, prinly reflexed, 9 to 15 mm. long, their tips free in the bud; petals purplish or crimson, with a large purple splotch in center or at apex, and often (always?) yellow at base, 1.1 to 2.5 cm. long; stamens

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about one-half the length of the petals or less; anthers yellow, 5 to 7 mm. long, longer than the filaments; style as long as or longer than the stamens; stigmas purple, linear-oblong to oblong, 1 to 2 mm. long, hispidulose; capsule puberulent, sessile or rarely with a pedicel 1 mm. long, 4-sided with 2 ribs on each side, or those of the lateral faces obscure or wanting; seed very short, weakly margined. (Pl. 29, fig. 4.)

Tejon Cañon and northward through the Sierra Nevada Mts., 1500 to 5000 ft.: Greenhorn Range; Tule River; Halsted's Ranch, North Fork Kaweah, *W. L. J.*, no. 572; Fort Miller on the San Joaquin River (*Heermann,* type locality of *G. Williamsonii*); Big Meadows, Coulterville-Yosemite Trail, *W. L. J.*, 1896; Yosemite Valley, *W. L. J.*, 1896; Groul's Meadow, Tuolumne River; Knight's Ferry, *Bigelow* (cited in Pac. R. Rep., vol. 4, p. 86); El Dorado, Calaveras Co., and northward to Oregon. The calyx-tube in anthesis is usually twice as long as in bud. Simple-stemmed dwarfs of poor soil or unfavorable altitudes are only 6 cm. high, and have few flowers or even only one although but little smaller than the average of the species (La Grange, *W. L. J.*, July, 1896). Hall's no. 3313 displays both strikingly pilose and merely pubescent ovaries.

The type of this species, first described as Oenothera viminea, is in the Kew Herbarium. It was cultivated from seed brought by Douglas from the "Aguilar River" in Oregon, the modern Umpqua. My notes on the type follow:

Leaves entire; petals 2 to 2.1 cm. long; calyx-tube 8 mm. long, with something of the membranaceous texture and "style" of G. Williamsonii; calyx-segments distinct, strictly reflexed; stigma broadly oblong, purple; capsule square, 2.4 cm. long, strongly 2-ribbed on the anterior and posterior faces. The original description (Bot. Mag. t. 2873) does not give the number of ribs; nor does Lindley. The capsules are not, however, at all mature.

I cannot resist the conclusion that Godetia viminea and Williamsonii are identical. Both, in well developed plants, have the same habit, long virgate branches, shining white stems, erect buds, large flowers, long "taut" calyx-tube, primly reflexed calyx-lobes, oblong purplish stigma and square capsules. There may be a slight difference in length of capsules. *G. viminea,*

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capsules, type, 2.3 to 2.4 cm. long. Howell says 1.9 cm. *G. Williamsonii,* capsules, usual form, 1 to 1.3 cm. long. Durand & Hilgard say 1.5 cm. But I find a capsule 2.2 cm. long on Greene's "El Dorado, June, 1889," which is surely Godetia Williamsonii and as surely equivalent to Bolander, no. 6367, which is an excellent match for the Douglas type. The ribbing of capsules in G. Williamsonii seems to be variable, that is, the 2 ribs may or may not be present on the lateral sides. The same fact appears to be true of the Oregon *viminea,* as also of the Californian aggregate *quadrivulnera.* Capsules in specimens rarely seem ripe, although the ribs appear very susceptible to pressure in drying. Dead ripe pods display uniformly 8 ribs in the above species, so far as I have observed.

Hooker's plate in the Botanical Magazine shows lilac flowers but Lindley's plate in the Botanical Register, t. 1220, shows a different color scheme—the flowers might be typical south Sierran *Williamsonii.* The plants were first flowered in the garden of the Horticultural Society, London, in June, 1828. Hooker published his plate that year and his specimen in the Kew Herbarium is labeled "Oenothera viminea. (Am. bor. occ. Dougl.) Hort. Soc. Hort. Lond. 14-7-28." Lindley's drawing was made from the same lot of plants in September of the same year. He does not refer to the conflict in color diagnoses.

The specimens examined I have arranged in a series, beginning with type of G. viminea and proceeding to typical G. Williamsonii: *Douglas,* type, seeds from Aguilar River, Oregon; *Bolander,* no. 6367, California; *Greene,* El Dorado, Calaveras Co., June, 1889; *Drew,* Groul's Meadow, Tuolumne Co., July 3, 1887; *Hall & Chandler,* Toll House, Fresno Co., no. 15; *Bridges,* nos. 83 and 108, California; *Lobb,* no. 127, California; *Bigelow,* Knight's Ferry; *W. L. J.,* Squaw Valley, Fresno Co., no. 2747 and no. 572, Kaweah; *Hall & Babcock,* 5089, Greenhorn Range; *Hall & Babcock,* 3313, Yosemite Park, Hog Ranch; *Ed. Palmer,* no. 66, June 7-15, 1888, Yosemite Park, Hog Ranch; *Coville & Funston,* no. 1074, Havilah, Kern Co.; *Coville & Funston,* no. 1217, Tejon Cañon.

Var. **Congdonii** Jepson, n. var. Three to 4.5 dm. high; buds loosely pilose; calyx-tips slender and very distinct; petals yellow at base.—Hetch-Hetchy, *W. J. Congdon.*

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Var. **incerta** Jepson, n. var. Very leafy, 2 to 4 dm. high; petals deep crimson, 1.2 to 2 cm. long; capsules abundant, 8-ribbed; stigmas oval.—Yosemite Valley.

Var. **Margaritae** Jepson, n. var. Buds and flowers few and widely scattered on the very slender stems; color scheme in dried specimens seemingly very different from type; calyx-tube very slender, 9 to 14 mm. long, the segments more or less cohering in anthesis.—Margarita Valley, San Luis Obispo Co., *Mrs. R. W. Summers.*

Refs.—GODETIA VIMINEA, Spach, Hist. Veg. Phan., vol. 4, p. 389 (1835).

Oenothera viminea Douglas, Bot. Mag., t. 2873 (1828); Lindley, Bot. Reg., t. 1220 (1829).

Oenothera Williamsonii Durand & Hilgard, Pac. R. Rep., vol. 5, pt. 3, p. 7, pl. 5 (1855); Watson, Proc. Am. Acad., vol. 8, p. 596 (1873).

Godetia Williamsonii Watson, in Bot. Cal., vol. 1, p. 230 (1876).

10. **G. parviflora** Jepson, n. comb.

Stems 1 to 7 dm. long, usually diffusely branching from the base, the branches numerous and wiry; leaves narrowly lanceolate or linear, 1 to 2.4 cm. long, the lowest oblong or oblong-ovate; calyx in bud 4-sided and its tips free, the segments in anthesis commonly distinct; calyx-tube pinkish, long and slender (5 to 10 mm. long), usually longer than the ovary and commonly swollen slightly at the summit of ovary; petals cuneate-obovate, rose-red, 8 to 15 mm. long, the long stamens two-thirds their length; style nearly or quite equaling the petals; stigmas purple, elliptic, somewhat united at base; capsule 9 to 18 mm. long, 1.5 mm. broad, teretish, rather strongly curved, obscurely 2-ribbed on the sides.

Dry soils, Monterey Co.: San Miguelito Rancho, *W. L. J.*, no. 1624, June 14-20, 1901; Santa Lucia Mts., *W. L. J.*, no. 1636, June, 1901; *G. R. Vasey,* 1880; Salinas Valley, *Brewer,* no. 519, May 1, 1861, typical but small plants; *Douglas,* 1830-32, who first collected it; Monterey, State Survey, *Guirado,* no. 638, is, doubtless, a young state. The Brewer and Guirado plants were included by Watson in his Oenothera tenella, Proc. Am. Acad.,

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vol. 8, p. 615. My no. 1636 is an exact duplicate of the Douglas plant in the Kew Herbarium which was first described as Oenothera viminea Douglas, var. parviflora? Hooker & Arnott, Bot. Beech. 342 (1841).

11. **G. quadrivulnera** Spach.

Erect, 2 to 5 dm. high, simple or with simple branches from below the middle; pubescent or puberulent; lowest leaves obovate or oblong, short (1 to 2.3 cm.), the upper narrowly or broadly linear, the uppermost lanceolate and somewhat conduplicate, 1.5 to 3.5 cm. long; flowers remote; calyx-lobes usually distinct and reflexed (in the earliest flowers sometimes united and turned to one side); petals lilac or pale crimson, usually with a spot at the top, 5 to 11 mm. long; longer stamens 4 to 6 mm. long, the shorter half as long and subsessile; filaments dilated downwards; ovary canescent to densely villous; style typically not exceeding stamens, the stigmas purple, short oblong; capsule sessile, sharply 4-sided, 1.5 mm. broad, 1.3 to 2.5 cm. long, often rather strongly beaked. (Pl. 29, figs. 2, 8, 15, 22, 27, 28.)

Open hillsides; the most common species throughout the Coast Ranges; also in Southern California and the Sierra Nevada Foothills and northward to the Columbia River (first collected by Douglas near Fort Vancouver). My no. 1626 is taken to represent type in California. Variable in stature, habit, color of flowers and in the pubescence, ribbing and length of capsules. The varieties named below are separable with difficulty. They look more unlike than do the accepted species but marks of separation have been sought in vain.

The Douglas plants are in the Herbarium of Hooker (label reads "N. W. C. Ama. D. Douglas") and in the Herbarium of Bentham (label as follows: "Oe. quadrivulnera. Very common near Fort Vancouver.") There are two plants in each collection, all quite alike, slender, 3.6 dm. high, the branches none or short and few; very leafy; herbage minutely pubescent; leaves linear, 2.3 to 3.5 cm. long, 1.8 or 2 to 3 mm. broad, sessile or subsessile, those in the axils (fascicles) smaller; petals 7 to 11 mm. long; calyx-segments distinct, reflexed, 5 to 8 mm. long; ovary densely white pilose, 9 mm. long; calyx-tube 3 mm. long; no fruit.

In a specimen labeled "Oenothera quadrivulnera, Hort. Soc.

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Hort. Lond. 22-6-28" (which is undoubtedly from same seed as plant illustrated and described by Lindley in publishing the species) we have a more branched plant; longer stamens, 3.5 mm. long, the shorter half as long (or scarcely longer) and with *very short* filaments; style equaling long stamens; ovaries not as pilose-woolly as in the wild specimens; pods pubescent, square, a trifle under 2 mm. broad, 1.7 to 1.8 cm. long, flat on the lateral sides, 2-ribbed faintly on the anterior and posterior faces or 8-ribbed indistinctly. This garden plant must be taken as the type.

Another specimen labeled "Oenothera quadrivulnera. Common on the banks of streams in gravelly soils, flor. June. Augt. 9. Douglas," is rather widely branched from the base, lowest branches longest; pods *short,* but showing 4 ribs. This plant is attached to a sheet of Bot. Reg. t. 1119 in Herbarium Lindley. Finally I say that I see no difference of any moment between the garden plants and the wild plants mentioned save amount of pubescence.

The following new varieties are here indicated:

Var. **apiculata** Jepson, n. var. Pale, slender; buds strongly apiculate.—Howell Mt., *W. L. J.*, no. 2441.

Var. **Vacensis** Jepson, n. var. Often branched at the base, the stems slender; flowers very remote; capsules slender, 3 cm. long.—Vaca Mts., *W. L. J.*

Var. **Davyi** Jepson, n. var. Leaves all or mainly oblong and mostly obtuse, about 1.2 cm. long; midrib of valves prominent, ribs none or 4.—Point Reyes, *Davy,* no. 6701.

Forma **flagellata** Jepson, n. form. Simple or with few elongated very slender whip-like branches, 3½ to 6 dm. high, the flowers very remote.—Vaca Mts., *W. L. J.*, June 12, 1893.

Forma **Setchelliana** Jepson, n. form. Branching from base; young parts very canescent; style longer than stamens; capsule short, densely short villous.—Santa Cruz Mts., *Setchell & Jepson,* June 20, 1896.

Var. **Hallii** Jepson, n. var. Freely branching, 6 dm. high; petals ovate, with an abrupt short small point, light pink with a sharply defined deep purple or reddish wedge-shaped spot at apex; stigmas very short, subquadrate; ovary and capsule hairy; ribs filiform.—Box Springs Mt., Riverside, *Hall,* no. 6241.

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Var. **rubrissima** Jepson, n. var. Petals roundish ovate, 9 to 13 mm. long, uniformly deep reddish purple; ovaries canescent; capsules strigulose-pubescent.—Box Springs Mt., Riverside, *Hall,* no. 6240.

Refs.—GODETIA QUADRIVULNERA Spach, Hist. Veg. Phan., vol. 4, p. 389 (1835); Brewer & Watson, in Bot. Cal., vol. 1, p. 230 (1876); Jepson, Fl. W. Mid. Cal. p. 334 (1901).

Oenothera quadrivulnera Douglas, in Lindley, Bot. Reg., t. 1119 (1827); Watson, Proc. Am. Acad., vol. 8, p. 598 (1873).

12. **G. Goddardii** Jepson, n. sp.

Simple or sparingly branched, 3 to 7 dm. high, foliage and buds as in preceding but spikes not so lax; petals pink-crimson or purple-crimson, with or without dark crimson spot at apex, 0.5 to 1.3 cm. long; calyx-lobes primly reflexed, in pairs or quite distant; fruit sessile, 8 to 15 mm. long, almost glabrous or canescently puberulent, terete, 8-ribbed, and with 8 distinct but small nerves which are median and at the sutural angles.

Coast Ranges, dry hills: Hupa wagon trail near Redwood Creek, *W. L. J.,* no. 1971; Mt. St. Helena, *W. L. J.,* July 19, 1894; Napa Soda Springs, *W. L. J.* (= G. albescens var. micropetala Jepson, Fl. W. Mid. Cal. p. 334); Fish Ranch, Contra Costa Co., June 9, 1890, *W. L. J.* Named in honor of Dr. Pliny E. Goddard of the University of California, a student of the food and ceremonial plants of the Hupa tribe, and my traveling companion on an expedition to the South Fork of the Salmon River in 1902 when the type specimens were collected. There are transition forms to the preceding.

Var. **Miguelita** Jepson, n. var. Branching mainly above (sometimes simple); petals deep crimson; capsules pilose or pubescent, short (1 to 1.6 cm. long) and thick (3 cm. broad), strongly 2-ribbed on each side and strongly nerved at the angles, very shortly pediceled.—San Miguelito Rancho, *W. L. J.,* no. 1625.

Forma **capitata** Jepson, n. form. Stem about 5 cm. high, with simple secondary branches from the base, 0.5 to 1.5 cm. long; herbage puberulent; flowers in a head-like bracteate cluster at end of branches, the ovaries densely pilose.—Centreville, Fresno Co., *W. L. J.,* no. 2745.

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13. **G. epilobioides** Watson.

Slender, simple, or nearly so, erect, 1.5 to 3.5 dm. high, minutely puberulent; leaves oblong, remotely and minutely toothed, 11 to 23 mm. long; petioles 5 mm. long or less, the uppermost leaves nearly sessile; buds nodding, the tip of the calyx-lobes not free; calyx-tube 1 mm. long; calyx-lobes united and turned to one side in anthesis, 6 mm. long; petals obovate, commonly cream-yellow, rarely lavender-pink and dotted on the lower half, 6 to 9 mm. long; stamens about half the length of the petals; anthers 1 mm. long, nearly twice the length of the filaments; stigmas very slightly lobed, as if capitate; capsule 4--sided, with plane or flattish faces, or with the reddish or brown midnerve somewhat depressed, 1.4 mm. broad, 2 to 2.5 cm. long, pedicels 5 mm. long or less, sometimes very short but always present.

San Diego (*Nuttall*, type locality); San Jacinto River, *W. L. J.*, no. 1265; San Bernardino Mts., *Vasey;* Santa Catalina Island, *Trask;* Casitas Pass, Ventura Co., *Hall*; and north to Arroyo Grande, *Alice King*. Apr.-June. I have seen no specimens save from Southern California. It may occur as a freight train immigrant at Antioch. The books say north to British Columbia but the authors and collectors in this case mistake their species. For instance, Macoun's 253, Vancouver Island, distributed as this species, equals G. amoena with large 4-spotted flowers and big round capsules.

The type in the Kew Herbarium is labeled as follows: "Oenothera * epilobioides. U. Calif." in hand of Nuttall. Another specimen on same sheet in hand of Nuttall: "Oenothera epilobioides, St. Diego, U. Cal." Type is the exact equivalent of my no. 1265, San Jacinto River, 1901, and is a very slender plant; capsules slender, 4-sided, smooth, falsely terminal through pushing aside the growing shoot, on pedicels 4 mm. long. In Coulter's specimen one pedicel is as much as 5 mm. long. I find no capsules in any specimen quite sessile, *i.e.*, in which a slight pedicel-like constriction cannot easily be made out.

Nuttall always marked the specific name on the label of his specimens which were new species with a star as is indicated in the above transcript.

Refs.—GODETIA EPILOBIOIDES Watson, in Bot. Cal., vol. 1, p. 231 (1876).

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Oenothera epilobioides Nuttall, in Torrey & Gray, Fl. N. Am., vol. 1. p. 511 (1840); Watson, Proc. Am. Acad., vol. 8. p. 599 (1873).

14. **G. purpurea** Don.

One to 3 or 6 dm. high, typically simple and usually stoutish, the flowers capitately congested at the summit or disposed in the upper axils of the leafy stem, the single flowers sometimes replaced by a cluster of 2 to 4 and borne on very short branchlets; leaves and younger parts of stem minutely pubescent; leaves ovatish-oblong or oblong, obtusish or merely acute, the upper oblong-lanceolate or lanceolate, 1.5 to 3.5 cm. long, 3 to 10 mm. broad, entire or sparingly and remotely denticulate, sessile or very shortly petioled, 3 to 10 mm. broad, 1.5 to 3.5 cm. long; buds erect, commonly pilose, their calyx-tips but slightly free; sepals distinct, about 1 cm. long; calyx-tube 5 to 7 mm. long and 3 to 5 mm. broad at apex; petals broad wedge-shape, truncatish and eroded at apex, 1 to 2.2 cm. long, 0.6 to 1.6 cm. broad, light crimson usually with a wedge-shaped darker spot in middle at apex; stamens 5 to 10 mm. long; the short ones scarcely more than ½ as long and their filaments 1 to 2 mm. long, ½ to ⅔ length of long filaments; style shorter than the long stamens; stigmas oval, purple; ovary shaggy villous or canescent; capsule 4-sided, sessile, stoutish and mostly short, 1 to 1.4 (or 2.4) cm. long, shaggy or merely pubescent, 8-ribbed; seeds faintly granulate on sides. (Pl. 29, figs. 1, 6, 18, 21, 23, 24.)

Dry open valleys in May, in local spots where the surface soil is still moist at the end of the rainy season, widely distributed but not common: Sacramento valley, both east and west side, including the low foothills, and southward to Fort Tejon and Los Angeles. The original description by Curtis in 1795 (Bot. Mag. t. 352) was drawn from plants cultivated at Kew Gardens, the seed having been collected on the west coast of America in 1791 (therefore ? Menzies, between San Francisco and Monterey). I find no type specimens at Kew nor any early garden specimens of the time.

Specimens examined: State Survey, no. 690; Arroyo Grande, *Rev. R. W. Summers*, May 21, 1886; Oakland Hills, *Bolander*, 410; Bodegas, *Hinds;* Santa Margarita Valley, *Mrs. Summers*,

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June, 1882; Brown's Valley, *Jepson;* Hartley, *Baker,* no. 2884. These specimens, all except last in the University of California Herbarium, differ but slightly, and chiefly in degree of shagginess of fruit. I take all the above to be good Godetia purpurea. My reasons are two: First, the earliest garden specimens in the Kew Herbarium (1825-1835) have the same characters of broad obtusish leaves, large flowers congested at the ends of the branches, rarely somewhat spicate, square, more or less hairy or shaggy 8-ribbed fruits. The garden specimens differ only in that they are usually branched, but the branches are simple. Doubtless this branching is due to cultivation. Moreover State Survey, no. 690, which I take to be very typical, is *slightly* branched just as in the figure of type. It corresponds very well with figure and with garden specimens. Secondly, the specimens of the early collectors, Douglas, etc., which were labeled G. purpurea were determined by men who had G. purpurea before them in the garden where, as a solitary west American Godetia, it had been grown a long time. The following are labeled by W. J. Hooker and Geo. Bentham as G. purpurea: "Californie, *D. Douglas*"; "California. *Douglas,* 1833;" "Woods near Monterey, *Hartweg,* 1730." The last has very short branches which bear 1 to 3 pods each on the upper half; in other words single pods are replaced by 2 or 3 on *very* short branches. Watson, Proc. Am. Acad. 8; 578, refers Hartweg's 1730 to G. albescens; he lays stress upon the short branchlets, a feature which I had noticed before discovering Watson's note and decided it was a case of vegetative variability and of slight account.

I would also add the following: Tejon Cañon, *Coville & Funston,* no. 1216; Pacific Grove, *Chandler,* no. 354, flowers less numerous and smaller; Santa Barbara, *A. D. E. Elmer,* no. 3791, May, 1902; College City, *Alice King,* 1906; Willows, *W. L. J.,* May 1, 1899.

The typical state often runs into small forms with small and few flowers which are mere seasonal or arid variations, but which are easy to confuse with depauperate forms of G. quadrivulnera or G. Goddardi. I also indicate the following:

Var. **Elmeri** Jepson, n. var. Flowers loosely spicate below the dense terminal cluster of young buds; petals broadly ovate,

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dark red in the dried specimens, 1.4 cm. long; capsule stout and rather short.—Santa Barbara, *Elmer*, no. 3972.

Var. **procera** Jepson, n. var. Slender, tall (5.5 to 7.5 dm. high), simple or with few short slender branchlets; flowers small, the petals 5 or 6 mm. long.—Berkeley, *Bioletti*, July, 1891.

Var. **lacunora** Jepson, n. var. Tall (4 or 5 dm. high), freely branching, upper portions of the branches angled (!) or compressed (!); flowers congested at the ends of the branches; petals .8 to 1.3 cm. long—Oakdale, San Joaquin Valley, *W. L. J.* (leaves acute); *Douglas*, probably Monterey Co. (leaves obtusish, or in Herb. Lindley acutish), branches strict, slender, naked except at tip!

Refs.—GODETIA PURPUREA Don, in Swett, Hort. Britt., ed. 3, p. 237 (1839); Brewer & Watson, in Bot. Cal., vol. 1, p. 229 (1876).

Oenothera purpurea Curtis, Bot. Mag., t. 352 (1795); Watson, Proc. Am. Acad., vol. 8, p. 596 (1873).

15. **G. Arnottii** Torrey & Gray.

Simple, 1.5 to 3.5 dm. high, wholly glabrous; leaves thickish, rhomboidal-ovate to oblong or oblong-lanceolate, entire or sparingly denticulate, 1.5 to 4 cm. long, .4 to 1.8 cm. broad, subsessile; calyx-tips free in bud; flowers congested in a terminal head; calyx-tube 3 mm. long, the segments distinct; petals rose-red, with whitish base, orbicular, entire, 1.3 cm. long; long stamens 6 mm. long, exceeding the style, the short stamens ½ to ⅔ as long; stigma ? whitish or pale crimson; ovary deeply grooved, quite glabrous in the interior form; capsule teretish, 8-ribbed, 1.3 cm. long. (Pl. 29, fig. 25.)

Open sterile sandy-clay fields of the Sacramento Valley; Little Oak, Solano Co., *W. L. J.*; Elmira, *C. F. Baker*; presumably southward through the San Joaquin and thence westward to the coast, since the original specimens by Douglas came with scarcely a doubt from the region between Monterey and San Luis Obispo.

The type specimen of Godetia Arnottii was first referred to in a note under Oenothera viminea by Hooker & Arnott, Bot. Beechey, p. 342. This is the first reference to these plants. The type was collected by Douglas in California, probably between

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Monterey and Santa Barbara as G. Arnottii is of that interior flora of California which also runs out to the coast south of Monterey. My Little Oak specimen, Solano Co., Sacramento Valley, is typical.

Torrey & Gray described the specimens sent them by Hooker as Oenothera Arnottii. They had, from the description I should say, the usual form. The Douglas plant here at Kew has minutely puberulent herbage, stem above very angular, leaves entire or remotely denticulate, about 3 cm. long and 6 mm. broad (smaller leaves fascicled in the axils); flowers in dense terminal tuft on the simple stem; calyx-tube 4 mm. broad at summit, 4.5 mm. long; petals 1.6 cm. long and 1.3 cm. broad; style not exceeding stamens, merely 4-lobed; ovary minutely and sparingly puberulent, deeply grooved; capsules sub-puberulent, square, short, or the most fully grown 1.5 cm. long, 2.5 mm. broad, the ribbing not very obvious except on one capsule less fully developed which shows plainly 8 ribs.

Refs.—GODETIA ARNOTTII Walpers, Rep., vol. 2, p. 88 (1843).

Oenothera Arnottii, Torrey & Gray, Fl. N. Am., vol. 1, p. 503 (1840).

Oenothera lepida, Hooker & Arnott, var. *Arnottii,* Watson, Proc. Am. Acad., vol. 8, p. 597 (1873).

Godetia lepida Lindley, var. *Arnottii,* Bot. Cal., vol. 2, p. 229 (1876); Jepson, Fl. W. Mid. Calif., p. 335 (1901).

16. **G. sparsifolia** Jepson, n. sp.

Simple or branching at the base, 2.8 dm. high; flowers collected in a dense and leafy terminal cluster, the stem sparsely leafy below; leaves linear-oblong, acute, 2 to 3 cm. long, sessile; herbage pubescent or pilose, the deeply grooved ovary densely hairy; sepals distinct, calyx-tube narrow, 3 mm. long; petals oblong-ovate, purplish with a spot towards summit, 10 mm. long; stigma almost entire, purple; style as long as the long stamens, about half the length of the petals; capsule unknown.

San Joaquin Valley at Tracy, *Benj. Cobb,* Apr. 10, 1900.

17. **G. grandiflora** Lindley.

Stout dwarf, simple, or with short slender branches above the base, 2 to 3 dm. high, very leafy; herbage minutely strigulose;

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leaves oblong, tapering strongly to apex and to the short petiole at base, 4 to 9 mm. broad, 2 to 6.5 cm. long; calyx-buds very large, 3 to 4.5 cm. long, the tips not free; flowers in a short spike or dense cluster of short subterminal branchlets; calyx-lobes united and turned to one side in anthesis; petals cuneate-obovate, retuse at apex, 2.5 to 3.5 cm. broad, 4 to 4.5 cm. long, rose-red with a deeper flush or blotch in centre; stamens ⅖ length of petals; style as long as stamens; stigmas yellow, linear, 6 mm. long; capsules canescent, thick and short, 2 cm. long, strictly sessile; seeds in two rows in each cell (!).

North coast of California: Duncan's Mills, *Harford,* 1868; "plains" at Shelter Cove, Humboldt Coast, *Bolander,* no. 6534, 1867, type of *Oenothera Whitneyi* Gray; not since collected elsewhere in California. Originally described from garden specimens, the seeds sent to England from the Columbia River in 1845. Seed was also collected by Hinds, the garden specimens in Herb. Lindley with looser spikes. Prized in cultivation, the flowers 4 or 5 inches across.

Refs.—GODETIA GRANDIFLORA Lindley, Bot. Reg., vol. 27, Misc. 61 (1841); Brewer & Watson, Bot. Cal., vol. 2, p. 229 (1876).

Oenothera Whitneyi, Gray, Proc. Am. Acad., vol. 7, pp. 340, 400 (1868); Hooker, f., Bot. Mag., t. 5867 (1870).

Oenothera grandiflora Watson, Proc. Am. Acad., vol. 8, p. 596 (1873).

X.—LITTLE KNOWN SPECIES, OLD AND RECENT.

GODETIA TENELLA Steudel, Nom. ed. 2, vol. 1, p. 697 (1840). *Oenothera tenella* Cavanilles, Icon. vol. 4, p. 66, t. 396 (1797). Exact nature of type difficult to make out. Hooker (in Bot. Mag. t. 2424) notes that it may be the same as Oe. Romanzovii. His specimen, from which above cited figure was taken, is in the Hooker Herbarium, Kew; no Californian plant will match it. Flowers too large for what ordinarily passes as G. tenella in California; buds of different shape; capsule with strong midrib to valves and strongly nerved at the angles, the valves splitting through these strong angular nerves on dehiscence.

Cavanilles' table 396, Icon., vol. 4, is poor, as is Ruiz & Pavon's (Fl. Peruv. 3, t. 316). The figures show a more suffruticose plant

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than any North American Godetia. Ruiz & Pavon's description is doubtless better than Cavanilles', since they correct the latter in considerable detail.

In any event I am sure that the Watsonian G. tenella as exampled by State Survey, no. 519, teste Watson, cannot be true G. tenella. The style is far too long; that organ in true tenella does not exceed stamens. "Stylus stamibus brevior" say R. & P. So, also, figure in Botanical Magazine. Moreover, consider the remarkable length of the calyx-tube, often longer than the ovary! I feel satisfied in excluding G. tenella from the Californian flora.

GODETIA ROMANZOVII Spach, Hist. Veg. Phan. vol. 4, p. 390 (1835); *Oenothera Romanzovii* Ledebour, ex. Hornem. Hort. Hafn. Suppl. 133. Known only from garden specimens, the seed collected by Chamisso on the "Northwest Coast." There are five specimens in the Kew Herbarium (4 sheets), all as much alike as could well be wished. All are very leafy with oblong-oblanceolate petioled leaves 5 cm. long or less, all *white*-pubescent (the pubescence very *close* and *felt-like*) on the young parts at the end of the stem and branches, that is buds, ovaries, stem, base of leaves. The leafiness is very marked, even to the end of the branches. There is thus a white *splotch*, due to canescence, in the end of the branch, the glabrous or at least green terminal leaves extending beyond it. Petals 1.1 to 1.4 cm. long, calyx-tube short 2 to 5 mm. long; capsules 1.6 to 1.9 cm. long, squarish, not obviously ribbed, very canescent.

There is more variation in capsules than in other parts; those from the St. Petersburg garden are a bit rusty, not so wide and more distinctly square than those on "Hort. Soc. Hort. Lond. 1830," where they are quite thick, thus emphasizing the *shortness*. The latter is matched by another sheet "Ex. Am. Boreali Occ. Douglas. Hort. Soc. Hort. Lond. 14-7-28" with shorter stamens, anthers 2.5 mm. long on filaments rather less than 1 mm. long; longer stamens 5 mm. long, the filaments relatively longer than in short stamens; stigma looking as if capitate and scarcely protruding beyond the calyx-tube.

Botanical Register, t. 562, is faithful to the herbarium specimens, or rather corresponds with them. The foliage in herbarium specimens is not silky but weakly puberulent.

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GODETIA DECUMBENS Douglas, Bot. Mag., t. 2889 (1829).

Stems strongly flattened, branching, decumbent or erect, 1 to 2 feet high; herbage with short half-appressed white hairs; leaves broad, ovate-lanceolate, bluntish or short-acute; petals crimson-purple, whole colored or blotched at apex; stamens nearly half length of petals; ovary pointed, thickish below, white woolly; pods 2 to 2.6 cm. long, very square, with a strong central midrib, hairy.

No specimens other than garden specimens are certainly referred here in this paper. The species was first published in the Botanical Magazine, t. 2889. The figure in the Botanical Register t. 1221, was from plants from the same (first or second year) sowing, yet one would easily take it that the two plates represented different species! In one the flowers are dark purple, in the other crimson. Both plates were published in 1829. Douglas sent the seeds from the mountain valleys of "northern California," *i.e.*, Oregon, as he did not visit California proper until 1830. The plants flowered first in the same year. The Botanical Register plate was made from plants of the second generation. Most likely, too, the Botanical Magazine plate.[3] I should say the latter were the poorer plate.

There is no difficulty in recognizing garden specimens of this in all the herbaria where I have seen it, Kew, British Museum, Berlin, Cambridge, by its ascending stems, its broad leaves, broadest below the middle and bluntish or at least short-acute, and white woolly thickish but pointed ovaries. The pods are not pointed (except at very tip), although they are very pointed when half-grown.

Putting Lindley's types of G. decumbens and G. lepida side by side, I could not doubt they were the same specifically. The resemblances are positive: both have the strongly *flattened* stems; the pods are alike (in *decumbens* a trifle less hairy); the leaves are alike (in *lepida* a shade more pointed but scarcely perceptible); and the pubescence is exactly the same. *G. decumbens* is not noticeably flexuous. The flowers may be different, the material not encouraging a comparison.

[3] Hooker's earliest garden specimens are marked "14-7-28."

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The plates of these two forms differ strikingly but no more than the two plates of either G. decumbens or G. viminea in the Botanical Magazine and Botanical Register. The material is nearest G. purpurea, differing chiefly in the well-scattered pods.

GODETIA *lepida* Lindley, Bot. Reg., t. 1849 (1836). The type (Hb. Lindley) is plainly from the same plant as that which furnished the drawing. Herbage to the eye glabrous but with a minute pubescence of short half-appressed white hairs; stem *flexuous,* and *strongly compressed* above; leaves thickish; a single flower; petals scarcely retuse, same size as in figure; long and short filaments 4 mm. and 1.5 mm. long respectively, the longer nearly half length of petals; capsules 2 to 2.6 long, very square, with a strong central mid-rib, and very hairy, although not densely so.

GODETIA ALBESCENS Lindley, in Bot. Reg., vol. 28, t. 9 (1842). Cultivated; seeds from the Columbia River sent by Dyer. The flowers in the figure are not very whitish. I find no example in Lindley's Herbarium and no specimens are before me which I could certainly refer to it. It is most probably a form of G. purpurea.

GODETIA MICROPETALA Greene, Pitt., vol. 1, p. 32 (1887). Type locality, "Hills along Walnut Creek." I have seen no specimens of this.

GODETIA PULCHERRIMA Greene, Pitt., vol. 2, p. 217. (1892). Type locality, "Los Angeles County."

GODETIA BINGENSIS, Suksdorf, Deutsch. Bot. Monatsschr., vol. 18, p. 88. Nearest G. quadrivulnera but my material too insufficient for definite decision.

GODETIA LANATA Elmer, Bot. Gaz., vol. 41, p. 318 (1906). Type locality, "Bardin's railroad switch, Monterey County." I have seen no specimens.

GODETIA LATIFOLIA Nelson & Kennedy, Proc. Biol. Soc. Wash., vol. 19, p. 156 (1906). Type locality Sierra Valley, Sierra County, California. This equals Clarkia rhomboidea Dougl. according to Dr. H. M. Hall and Mrs. K. Brandegee.

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GODETIA DELICATA Abrams, Bull. Torr. Club., vol. 32, p. 539 (1905). Slender, mostly simple, 3 to 5 dm. high; herbage glabrous; flowers scattered; calyx-tube 1 or 2 mm. long, the lobes remaining united in anthesis and turned to one side; petals 7 to 9 mm. long, flabelliform or obovate, roundish at apex, at base gradually narrowed to a claw as long or half as long as the blade; stamens with hairy tufts at base of filaments; capsule 2 to 2.4 cm. long, filiformly 2-ribbed on anterior and posterior faces, the lateral faces with a broad but very shallow depression; seeds very short, ⅔ mm. long, not fimbriate margined, but obliquely truncate at each end.

Southern California: sandy slopes between Campo and Potrero, *Abrams,* type locality; Ramona, *Brandegee*, 1906. Material of this has been received since the body of the paper went to press. On account of the clawed petals, hairy ring at orifice of calyx-tube and smoothish capsules, this species serves to emphasize in a marked manner the close relation between Godetia and Clarkia. It is most nearly allied to Clarkia rhomboidea.

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XI.—INDEX.

PAGE

Clarkia 319
concinna 323
elegans 323
Eucharidium 319
Godetia albescens 351
var. *micropetala* 342
amoena 325, 322
var. **albicaulis** 329
var. **concolor** 328
f. **Huntiana** 329
var. **Lindleyi** 329
f. **pygmaea** 328
arcuata 335, 322
Arnottii 346, 322, 347
biloba 333, 322, 323
Bingensis 351
Blasdalei 330
Bottae 330, 334, 322
var. **cylindrica** 332
var. **usitata** 332
decumbens 350, 321, 351
deflexa 332
Dudleyana 333, 322
f. **Brandegeae**.....334, 323
epilobioides 343
Goddardii 342
f. **capitata** 342
var. **Miguelita** 342
grandiflora 347, 348, 322
Hansenii 336, 322
hispidula 335
jucunda 334
lanata 351
latifolia 351
lepida 351
var. *Arnottii* 347
micropetala 351
parviflora 339
pulcherrima 351
purpurea 344-346, 322
var. **Elmeri** 345

PAGE

var. **lacunora** 346
var. **procera** 346
quadrivulnera ..340-342, 338, 322
var. **apiculata** 341
var. **Davyi** 341
f. **flagellata** 341
var. **Hallii** 341
var. **rubrissima** 342
f. **Setchelliana** 341
var. **Vacensis** 341
Romanzovii 321, 349
rubicunda 330
sparsifolia 347
tenella 348
tenella 349
viminea 336-339, 322
var. **Congdoni** 338
var. **incerta** 339
var. **Margaritae** 339
viminea 330
vinosa 330
Williamsonii 337, 338, 339
Oenothera *amoena* 329
arcuata 335
Arnottii 347
biloba 333
Bottae 332
epilobioides 343, 344
grandiflora 348
lepida var. *Arnottii* 347
Lindleyi 329
purpurea 346
quadrivulnera 342
Romanzovii 349
roseo-alba 330
tenella 348
tenella 339
viminea 337, 339, 346
var. *parviflora* 340
Whitneyi 348
Williamsonii 339

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PLATE 29.

Fig. 1. Godetia purpurea Walp., flower bud.

Fig. 2. Godetia quadrivulnera Spach, flower bud.

Fig. 3. Godetia biloba Wats., flower bud.

Fig. 4. Godetia viminea Spach, flower bud.

Fig. 5. Godetia arcuata Jepson, flower bud.

Fig. 6 Godetia purpurea Walp., petal.

Fig. 7. Godetia Dudleyana Abrams, forma Brandegeae Jepson, petal.

Fig. 8. Godetia quadrivulnera Spach, petal.

Fig. 9. Godetia biloba Wats., petal.

Figs. 10-14 Godetia biloba x Clarkia concinna, petals showing variation in lobation, all from one plant.

Fig. 15. Godetia quadrivulnera Spach, style and stigma.

Fig. 16. Godetia Dudleyana Abrams, style and stigma.

Fig. 17. Godetia arcuata Jepson, style and stigma.

Fig. 18. Godetia purpurea Walp., style and stigma.

Fig. 19. Godetia amoena Lilja, cross-section of ovary.

Fig. 20. Godetia arcuata Jepson, cross-section of ovary.

Fig. 21. Godetia purpurea Walp., cross-section of ovary.

Fig. 22. Godetia quadrivulnera Spach., cross-section of ovary.

Figs. 23-24. Godetia purpurea Walp., cauline and bracteal leaves respectively.

Fig. 25. Godetia Arnottii Torr. & Gr., extreme type of bracteal leaf.

Fig. 26. Godetia arcuata Jepson, typical cauline leaf.

Figs. 27-28. Godetia quadrivulnera Spach, cauline and bracteal leaves respectively.

Figures 1-14 are natural size; figures 15-18, twice natural size; figures 19-22, four times natural size; figures 23-28, natural size.

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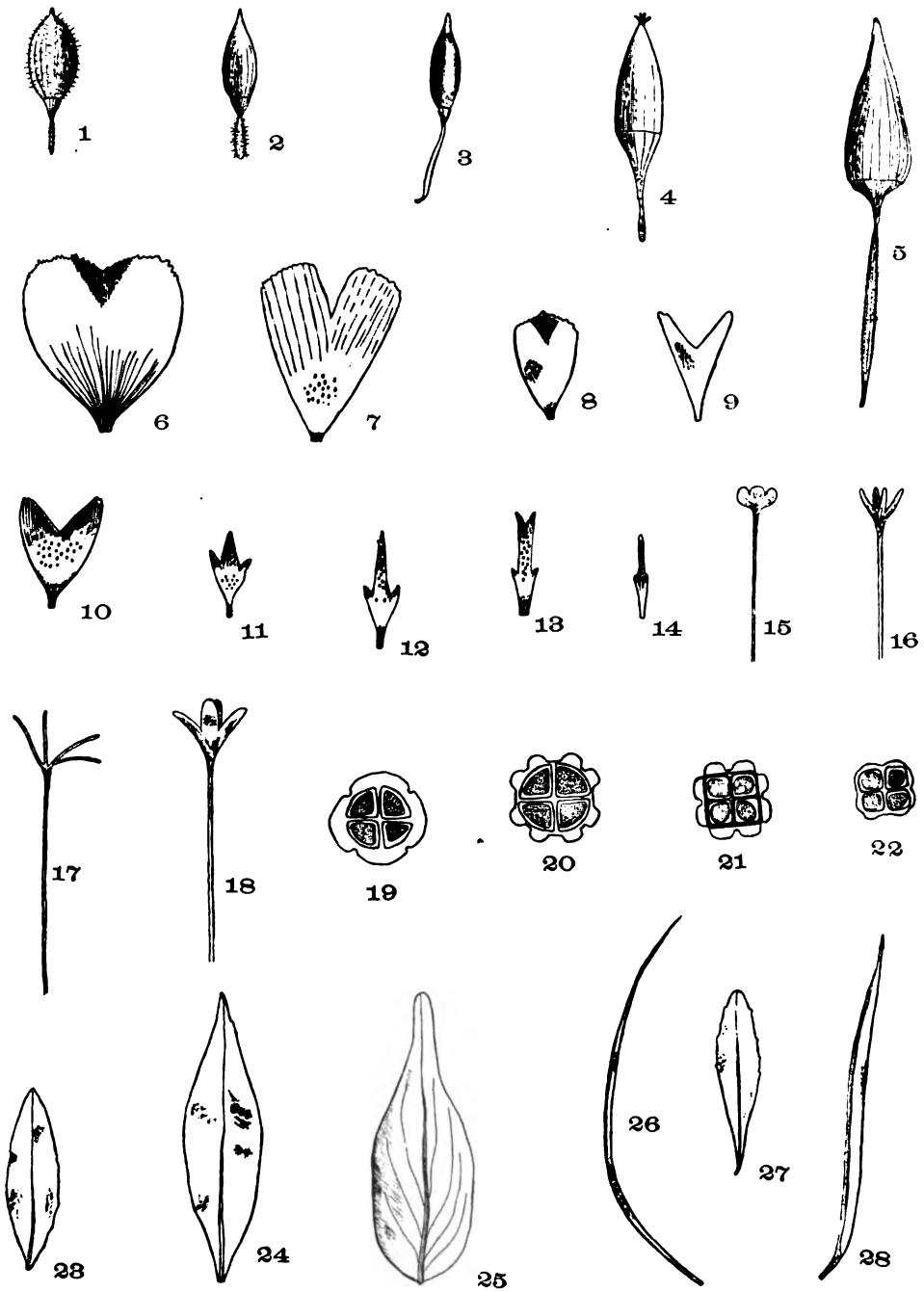

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INDEX.*

Aalaula, 96, 97, 107, 112, 113.
Agaricus, 176.
Agarum fimbriatum, 125, 126.
  Turneri, 124, 125, 126, 150.
Ahnfeldtia Polyides, 97.
Akiaki, 93, 96, 97, 98, 102, 103.
Ahnfeldtia concinna, 97.
  Gigartinoides, 97.
Ako'ako'a, 97.
Alaalaula, 97.
Alani, 97.
Alaria esculenta, 117, 146, 149, 158.
Alaskan Sphagna, Some Unreported, 309.
Alaula, 96, 97.
Algae, 311.
Amansia glomerata, 106.
Amphoridium lapponicum, 299.
Anabaena, 239.
  Azollae, 239.
  catenula, 250.
  flos-aquae, 239, 251.
  variabilis, 239, 271.
Anadyomene stellata, 158.
Antitoxic Action of Potassium on Magnesium, 235.
Antitrichia curtipendula, 303.
Aphanizomenon Flos-aquae, 239.
Aphanothece, 239, 277.
Aqueous Media, Mounting in, 83.
Arctium Lappa, 159.
Arthrothamnus bifidus, 128.
  Bongardianus, 117, 121.
  Bongardianus var. furcatus, 121.
Ascomycetous Fungi, New Genus of, 169.
Asparagopsis Sanfordiana, 103, 104, 105.
Atonement Limu, 96.
Aulacomnium palustre, 303.
Aupupu, 97.

Balanced Solutions, and Nutrient, 317.
  For plants, On Physiologically, 231.
Bartramia ithyphylla, 300.
Beggiatoa, 278.
  alba, 278, 279.
  arachnoidea, 240, 279.
  mirabilis, 240, 278, 279.
Begonia, 157.
Blindia acuta, 298.
  var. flexipes, 298.
Boletus, 176.
Brachythecium lamprochryseum, 304.
Bryum Graefianum, 301.
  inclinatum, 301.
  Kaurinianum, 301.
  pseudo-Graefianum, 301.
  Setchellii, 302.
Bryophytes, 312.
Burdock, 159.

Calothrix, 251.
  Braunii, 239.
  crustacea, 239.
  parietina, 239.
Catharinea tschuctschica, 303.
Ceratodon purpureus, 298.
Centroceras clavulatum, 102, 112.
Chaetomorpha antennina, 109.
Chamaesiphonaceae, 239.
Chondrus affinis, 102.
Chorda filum, 116.
  tomentosa, 116.
Chroococcaceae, 239.
Claviceps, 311.
Climacium ruthenicum, 304.
Codium Muelleri, 96, 97, 113.
  spongiosum, 100.
Colonectria Massariae, 176.
Colpomenia sinuosa, 113.
Conostomum boreale, 300.
Contributions to Cytological technique, 73.
Cyanophyceae, 237.
  Cytological Studies in, 237.
Cylindrospermum, 251, 259, 264, 271.
  licheniforme, 239.
  macrospermum, 251.
  majus, 239.
Cynodontium Wahlenbergii, 297.
Cytological Studies in Cyanophyceae, 237.
Cytological Technique, 73.

* Vol. 2, Univ. Calif. Publ. Bot.

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Dehydration, Embedding with Incomplete, 87.
Dermocarpa, 264, 267, 280, 281.
fucicola, 239, 264.
prasina, 239, 264.
Desmatodon latifolius, 298.
Dicranella cerviculata, 297.
Grevilleana, 297.
Dicranum elongatum, 297.
groenlandicum, 297.
neglectum, 297.
Dictyosphaeria favulosa, 107.
Dictyotaceae, 106.
Dictyota divaricata, 106.
patens J., 106.
Distichium capillaceum, 298.
Dodder, 102.

Ecklonia bicyclis, 128, 129.
buccinalis, 118.
cava, 129, 130.
Ectocarpus confervoides, 230.
Ehau, 97.
Eisenia arborea, 126, 128, 129, 149.
arborea f. bicyclis, 129.
bicyclis, 129, 149.
Ekaha, 97.
Ekahakaha, 96, 98.
Eleau, 98.
Eleele, 98.
Embedding with Incomplete Dehydration, 87.
Microscopic Algae, 85.
Empusa Muscae, 311.
Enteromorpha, 234.
Hopkirkii, 229, 234.
intestinalis, 98.
Eurhynchium strigosum var. fallax, 304.

Fixation in Vacuo, 78.
Freezing Microtome, 73.
Fucus, 157, 158.
Fungi, 311.
Fungi, New Genus of Ascomycetous, 169.

Galaxaura lapidescens, 113.
rugosa, 102, 110.
Gelidium Amansii, 107.
capillaceum, 154.
filicinum, 108.
Gloeocapsa, 251, 252, 253, 255, 257.
polydermatica, 251.
Gloeotrichia, 251.
Gracilaria coronopifolia, 104, 108.
Grateloupia filicina, 99.
Grimmia apocarpa var. gracilis, 298.
maritima, 298.
Guignardella Alaskana, 312.
Gymnogongrus vermicularis f. Americana, 102.

Godetias, Synopsis of the North American, 319.
Index, 353.

Hafgygia Bongardiana, 118.
Bongardiana forma subsessilis, 119, 121.
Sinclairii, 142.
Haligenia bulbosa, 116.
Halimeda, 97.
Haliseris plagiogramma, 106.
Hassallia byssoidea, 239.
Hedophylleae, 126.
Hedophyllum sessile, 119, 120, 123, 126.
spirale, 120, 122, 125, 126, 128.
subsessile, 118, 120, 121, 122, 125, 126.
Heterocysteae, 239.
Hihimanu, 107.
Hinaula, 98.
Holomoku, 99.
Homocysteae, 239.
Hona, 99.
Hoonunu, 99.
Huahuakai, 99.
Huluhuluwaena, 93, 95, 99, 111.
Huluilio, 99.
Hululio, 99.
Huna, 99, 100.
Hune, 100.
Hunehune, 100.
Huwae, 100.
Huwai, 100.
Hydroclathrus cancellatus, 113.
Hylocomium rugosum var. boreale, 305.
splendens, 305.
squarrosum, 305.
triquetrum var. behringianum, 305.
Hypnea nidifica, 99, 100, 109, 110.
Hypnum, Bestii, 304.
capillifolium, 304.
Crista-castrensis, 304.
Dieckii, 304.
fluitans var. brachydictyon, 304.
fluitans var. falcatum, 304.
giganteum, 305.
var. fluitans, 305.
pseudo-sarmentosum, 305.
rugosum β imbricatum, 305.
sarmentosum, 305.
Schreiberi, 305.
stramineum, 305.
uncinatum, 304.
Hypocrea, 178.
inclusa, 176.
rufa, 176.
Hypomyces chrysospermus, 176.
Melanostigma, 176.
terrestris, 176.
tubericola, 176.

Digitized by Google

Ilioha, 100.

Jania rubens, 99.
Juglans, 207.

Kahakala, 100.
Kala, 100.
Kalalauliilii, 101.
Kalalaunuinui, 101.
Kaunoa, 102.
Kele, 102.
Kelps, Regeneration among, 139.
Kiki, 102.
Koeleele, 96, 97, 98, 102, 103.
Kohu, 103.
Koiale, 103.
Koko, 103.
Koloa, 103.
Kukaepueo, 103.
Kulapepeiao, 104.
Kumulimukala, 104, 107.
Kumulipoa, 104, 107.

Laminaria Andersonii, 145, 149.
  apoda, 119.
  Bongardiana, 149.
  Bongardiana f. bifurcata, 121.
  Bongardiana, forma brevipes, 121.
  digitata, 149, 158.
  Farlowii, 146.
  longicruris, 150.
  phyllitis, 117.
  saccharina, 116, 117, 126, 150.
  sessilis, 119, 121.
  Sinclairii, 121, 140, 141, 142, 144, 145, 146, 148, 149, 150, 151, 154, 158.
Laminariaceae, Post-embryonal stages of, 115.
Laurencia obtusa var. racemosa, 99, 100, 106, 108.
  perforata, 112.
Lessonia laminariaeoides, 146.
  litoralis, 118.
Liagora valida, 112.
Lichens, 312.
Limu, 91.
  akiaki, 97.
  alani, 97, 108.
  aupupu, 97.
  ekaha, 97.
  ekahakaha, 98.
  eleele, 98, 112.
  hinaula, 98.
  holomoku, 99.
  hona, 99, 100.
  huahuakai, 99.
  huluilio, 99.
  huna, 99, 100.
  hune, 100.
  hunehune, 100.
  kahakala, 100.
  kala, 96, 100, 101, 104.
  kalalauliilii, 101.
  kalalaunuinui, 101.
  kele, 102.
  kiki, 102.
  koeleele, 102.
  kohu, 103, 104.
  koiale, 103.
  koko, 103, 104.
  koloa, 103.
  kumulimukala, 104.
  kumulipoa, 104.
  lipahapala, 104.
  lipakai, 105.
  lipalao, 105.
  lipalawai, 105, 112.
  lipehu, 106.
  lipewale, 106.
  lipoa, 107.
  lipuula, 107.
  lipuupuu, 107.
  loloa, 107.
  lupe, 107.
  makaloa, 108.
  make, 97.
  maneoneo, 108.
  mauauwea, 108.
  nano, 109.
  nanoo, 109.
  nanue, 109.
  oaoaka, 109.
  ohiohio, 110.
  okupe, 110.
  oohiea, 110.
  opai, 110.
  paakai, 110.
  paakaiea, 110.
  pahapaha, 110, 111.
  pakeleawaa, 111.
  palahalaha, 111.
  palawai, 105, 112.
  pehu, 112.
  pepeiao, 112.
  pepeulu, 113.
  pipilani, 113.
  pupukaneilio, 113.
  salt, 104, 105, 110.
  uaualoli, 113.
  ulaula, 113.
  wawahiwaa, 113.
Limuaalaula, 96.
Limuhinaula, 98.
Limuhululio, 99.
Limuhuna, 100.
Limukahakala, 100.
Limukala, 100, 107.

Digitized by Google

Limukele, 102.
Limukiki, 102.
Limukoko, 103.
Limulipahapala, 104.
Limulipalao, 105.
Limulipalawai, 105, 112.
Limulipoa, 107.
Limulipupu, 107.
Limulipuula, 107.
Limulipuupuu, 107.
Limuloloa, 107.
Limunanue, 109.
Limuopai, 110.
Limupaakaiea, 110.
Limupalahalaha, 111.
Limupalawai, 105, 112.
Limupipilani, 113.
Limuulaula, 113.
Lipaakai, 104, 105, 106, 110.
Lipaha, 104.
Lipahapala, 104.
Lipahee, 105, 111.
Lipakai, 105.
Lipalahalaha, 105, 111.
Lipalao, 105.
Lipalawai, 105.
Lipalu, 106.
Lipeepee, 105, 107, 108, 112.
Lipehu, 106.
Lipewale, 106.
Lipoa, 92, 104, 106, 109.
Lipupu, 107.
Lipuula, 107.
Lipuupuu, 107.
Loloa, 107.
Lunularia, 157, 233, 236.
  vulgaris, 154, 158.
Lupe, 107.
Lyngbya, 234.
  aestuarii, 229, 239, 273, 277.
  Lagerheimii, 239, 270.

Magnesium, Antitoxic Action of Potassium on, 235.
Makaloa, 108.
Make, 108.
Manaiea, 108.
Manauea, 108.
Manauwea, 95, 108.
Maneoneo, 108.
Marchantia, 157, 158.
  polymorpha, 154.
Massaria inquinans, 176.
Mauauwea, 108.
Meesea uliginosa, 301.
Melanogaster, 176.
Melanospora Helvellae, 176.
Merismopedia, 270.
  Gardneri, 239.
  glauca, 239.
Microcoleus chthonoplastes, 239.
Microscopic Algae, embedding, 85.
Microtome, Freezing, 73.
Mnium insigne, 302.
  nudum, 302.
  punctatum, 302.
  punctatum var. elatum, 302.
  punctatum var. nudum, 302.
Monostroma, 105, 111, 112.
  latissimum, 110.
Mounting in Aqueous Media, 83.
Mualea, 108, 109.
Myrica, 207.

Nanea, 109.
Nanoo, 109.
Nanue, 109.
Nanui, 109.
Nectria lichenicola, 176.
  Robergei, 176.
Nereocystis, 118.
  Luetkeana, 149.
New Genus of Ascomycetous Fungi, 169.
Nigrosphaeria, 179.
  Setchellii, 179.
Nitophyllum multilobum, 230.
Nodularia armorica, 239.
  sphaerocarpa, 239.
Nohomahe, 109.
Nostoc, 251.
  caeruleum, 250.
  ellipsosporium, 239.
  microscopicum, 239.
  pruniforme, 239.
Nutrient and Balanced Solutions, 317.

Oaoaka, 109.
Octaviana, 176.
Ohiohio, 110.
Okala, 110.
Okupe, 110.
On a Small Collection of Mosses from Alaska, 297.
On the Importance of Physiologically Balanced Solutions for Plants, 230.
Oohiea, 110.
Oolu, 110.
Opai, 110.
Opihi, 95, 96, 99.
Orthotrichum arcticum var. Blyttii, 299.
  Blyttii, 299.
  cancellatum, 299, 300.
  fenestratum, 299, 300.
Oscillatoria, 251, 254, 268, 270, 275, 279, 280.
  acuminata, 240.
  amphibia, 240.
  animalis, 240.

Digitized by Google

Oscillatoria Bonnemaisonii, 240.
brevis, 240.
chalybea, 248, 259.
chlorina, 240.
curviceps, 240.
Froelichii, 251, 253.
geminata, 240.
imperator, 251.
laetevirens, 240.
limosa, 240, 250, 253.
margaritifera, 239, 259, 266, 272, 273, 279.
nigra, 251.
Okeni, 240.
proboscidea, 240.
tenuis, 240.
sancta, 240, 276.
simplicissima, 240.
splendida, 240, 250, 253, 266, 273.
Osmotic Pressure, in Marine Plants, Role of, 229.
Resistance of Certain Marine Algae to Changes in, 277.

Paakai, 104, 110.
Paakaiea, 110.
Padina Pavonia, 112.
Pahapaha, 110.
Pahapaha o Poli Hale, 111.
Pahee, 105, 111.
Pakaeleawa, 111.
Pakaeleawaa, 99.
Pakaiea, 100, 105, 110, 111.
Pakeleawaa, 111.
Palahalaha, 100, 111.
Palao, 105.
Palapahakou, 112.
Palawai, 105, 112.
Palewawae, 112.
Papaakea, 112.
Pehu, 112.
Peepee, 96, 112.
Pelagophycus giganteus, 149.
Pelea, 97.
Peltigera canina, 176.
Pelvetia, 157, 158.
Pepeiao, 112, 113.
Pepeulu, 113.
Perisporium agricola, 176.
Peziza hemisphaerica, 176.
Philonotis capillaris, 300.
fontana, 300.
fontana var. heterophylla, 300.
Phormidium, 251.
favosum, 240.
submembranaceum, 240.
uncinatum, 240, 276.
Phyllactinia fungicola, 176.
Phyllitis fascia, 116.
Pili-grass, 109.
Piliko'a, 113.
Pilipiliko'a, 112, 113.
Pinus pinaster, 177.
radiata, 177.
Pipilani, 113.
Plagiothecium neckeroides β myurum, 304.
undulatum var. myurum, 304.
Plocamium coccineum, 230.
Pogonatum alpinum, 303.
capillare var. dentatum, 303.
Poha, 113.
Polemoniaceae, Review of Californian, 1. Index, 69.
Polytrichum gracile, 303.
strictum, 303.
yukonense, 303.
Populus, 206.
Porphyra naiadum, 230.
Postelsia palmaeformis, 149.
Post-embryonal Stages of the Laminariaceae.
Potassium on Magnesium, Antitoxic Action of, 235.
Prasiola Gardneri, 238.
Pseudhydnotria carnea, 169, 177, 178.
Harknessii, 169, 170, 171, 174, 177, 178.
Psilopilum arcticum, 303.
tschuctschicum, 303.
Pteridophytes, 315.
Pterosiphonia, 234.
bipinnata, 230.
Pterygophora, 158.
Ptilota, 234.
filicina, 230.
Puha, 113.
Pupukaneilio, 113.

Ratfoot, 96.
Reduplication, 215.
Regeneration among Kelps, 139.
Resistance of Certain Marine Algae to Changes in Osmotic Pressure and Temperature, 227.
Reversion, 214.
Review of Californian Polemoniaceae, 1. Index, 69.
Rhacomitrium canescens, 298.
fasciculare, 298.
heterostichum, 298.
heterostichum f. stricta, 298.
lanuginosum, 298.
patens, 298.
Rivularia pisum, 251.
Role of Osmotic Pressure in Marine Plants, 229.
Ruppia, 230.
maritima, 229.
Russula, 176.

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Saccorhiza bulbosa, 116, 118.
dermatodea, 117, 118, 152.
Salix, 206, 207, 209.
aurita, 207.
babylonica, 182, 200, 202, 210.
laevigata, 210.
lasiandra, 182, 200, 202, 215.
lasiandra X babylonica, 196, 202, 209, 210, 211, 214.
lasiolepis, 182, 184, 194, 196, 198, 202, 204, 205, 208, 209, 210, 211, 213.
Nuttalli var. brachystachus, 210.
purpurea, 187.
Salt limu, 104, 105, 110.
Sargassum, 101.
echinocarpum, 101.
Scleroderma, 176.
Scytonema Javanicum, 239.
Sea-lettuces, 105.
Slide Holder, 81.
Some Unreported Alaskan Sphagna, 309.
Spermosira litorea, 251.
Sphaeria, 178.
(Hypocrea) Setchellii, 169, 179.
Sphaeroderma episphaericum, 176.
Sphagnum acutifolium var. versicolor, 313.
Dusenii var. majus, 313.
fimbriatum var. concinnum, 313.
fimbriatum var. flavescens, 313.
fimbriatum var. robustum, 313.
fuscum var., 313.
Girgensohnii, 313.
Lindbergi var. macrophyllum f. fluitans, 314.
Lindbergi var. mesophyllum, 314.
medium, 314.
medium var. obscurum f. brachydasycladum, 314.
platyphyllum var. immersum, 314.
recurvum var. amblyphyllum, 314.
rubellum, 314.
squarrosum, 314.
squarrosum var. imbricatum, 314.
squarrosum var. subsquarrosum, 314.
subbicolor var. flavescens, 314.
teres var. imbricatum, 315.
Warnstorfii var. flavescens, 315.
Warnstorfii var. purpurascens, 315.
Spirogyra, 235.
Spirulina, 251.
major, 240.
subsalsa, 240.
Splachnum sphaericum, 300.
vasculosum, 300.
Squid, 95.
Staminody, 214.
Symploca Muscorum, 240, 247, 248, 273, 276, 280.
Synechococcus, 239.
Synechocystis, 280.
aquatilis, 239, 268, 280.
Synopsis of the North American Godetias, 319.
Index, 353.

Technique, Cytological, 73.
Temperature, Resistance of Certain Marine Algae to Changes in Osmotic Pressure and, 227.
Teratology in the Flowers of Two Californian Willows, 181.
Thalassiophyllum clathrus, 123, 125.
Tetraplodon mnioides, 300.
mnioides var. cavifolius, 300.
Tolypothrix, 254.
lanata, 250, 251, 254.
Tuber alba, 176.
puberulus, 176.
Turbinaria, 101.
ornata, 101.

Uaualoli, 113.
Ulaula, 113.
Ulota phyllantha, 299.
Ulva, 105, 112.
fasciata, 110, 111.
Utricularia, 157.

Vacuo, Fixation in, 78.

Wawaeiole, 96, 113.
Wawahiwaa, 113.
Webera cruda, 301.
proligera, 301.
Willow, 159.
Willows, Teratology in the Flowers of Two Californian, 181.

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